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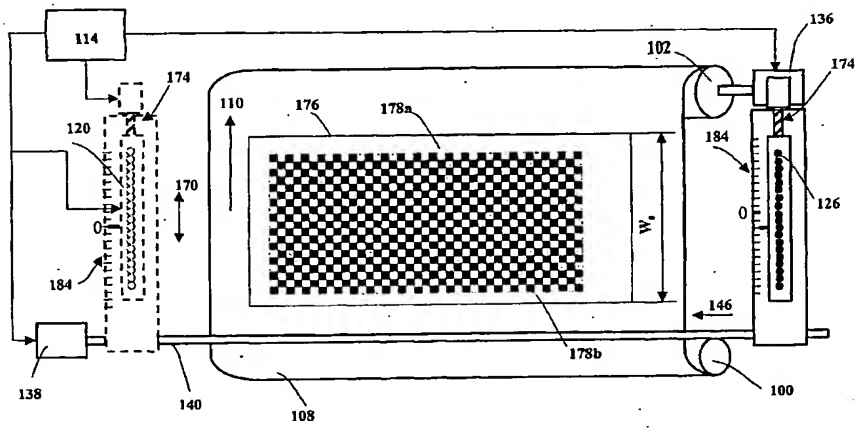

(57) Abstract: Disclosed is a method of multi pass inkjet printing on wide format flexible substrates where errors in flexible substrate positions are corrected by adapting the geometry and position of the next printed swath to the geometry of the adjacent earlier printed image swath.

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A METHOD OF PRINTING ON LARGE FORMAT FLEXIBLE SUBSTRATE AND PRINTING APPARATUS

FIELD OF THE METHOD

[0001] The method relates to the field of inkjet printing and particularly to printing on large format flexible substrates.

BACKGROUND

[0002] Inkjet printing has gained popularity in a number of applications. One of the growing printing applications is printing of billboards, banners and point of sale displays. The ink-jet printing process involves manipulation of droplets of ink ejected from an orifice or a number of orifices of a print head onto an adjacent print substrate. Paper, vinyl, textiles, fabrics, and others are examples of print substrates. An ink-jet print head consists of an array or a matrix of ink nozzles, with each nozzle selectively ejecting ink droplets. Relative movement between the substrate and the print head enables substrate coverage and image creation. Each ink droplet comprises an image (picture) element, or "pixel." For the simplicity of explanation the term "print head" will be used for both single print head and a plurality or print heads organized on a common mechanical structure.

[0003] Good print quality requires printing resolution higher than the native spacing of nozzles of most commercially available print heads. In order to cover the substrate with the desired print resolution a single print head scans the substrate in a reciprocating type of movement a number of times or passes. Such multi pass printing method contributes to print quality and provides a better redundancy, since different nozzles participate in printing sections of the same line when scanning the substrate in a reciprocating type of movement.

[0004] A majority of billboards and banners having relatively large dimensions are printed on flexible substrates. Roll-to-Roll (R2R) printing machines are typically used for printing on flexible substrates. One of the drawbacks of the Roll-to-Roll printing machines is the low accuracy of the relative movement between such a wide flexible

substrate and the print head. When pulled/moved flexible substrate easy stretches and deforms and accordingly changes its dimensions. This makes small, comparable with the printing resolution incremental movement of flexible substrate with accuracy of few microns nearly impossible.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The foregoing and other objects, features and advantages of the method and of the apparatus will be apparent from the more particular description of the exemplary embodiments of the method and of the apparatus, as illustrated in the accompanying drawings in which like reference numbers refer to the same parts throughout the different figures. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the method.

[0006] Figures 1A and 1B are schematic illustrations of an inkjet printer operating in a multi pass printing mode and a swath of an image printed by such a printer;

[0007] Figures 2A and 2B are schematic illustrations of an inkjet printer and an image printed by a multi pass printing method in accordance with the first exemplary embodiment of the method;

[0008] Figures 3A and 3B are schematic illustrations of an inkjet printer and an image printed by a multi pass printing method in accordance with the second exemplary embodiment of the method;

[0009] Figures 4A and 4B are schematic illustrations of an inkjet printer and an image printed by a multi pass printing method in accordance with the third exemplary embodiment of the method;

[0010] Figure 5 is a simplified flow chart of image on substrate position control marks placement decision making algorithm;

[0011] Figure 6 is an illustration of the fourth exemplary embodiment of the multi pass printing method;

[0012] Figures 7A and 7B are illustrations of the fifth exemplary embodiment of the multi pass printing method;

[0013] Figure 8 is an illustration of contact metering means.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0014] The principles and execution of a method and the operation and properties of an ink jet printing apparatus enabling the printing method may be understood with reference to the drawings and the accompanying description of non-limiting, exemplary embodiments.

[0015] Reference is now made to Figures 1A and 1B which are schematic illustrations of an ink jet printer and a multi pass printing method. Print head **120** is printing an image consisting of a number of swaths and a particular print swath of the image bounded by lines of rectangle **122**. Substrate **108** is advanced in the first direction indicated by arrow **110**. Print head **120** scans in the second direction indicated by arrow **124** and each of nozzles **126** of print head **120** prints respective line shown as separate pixels (black squares) **130a**. At the end of the scan, substrate **108** is advanced on a small, comparable with print resolution distance in the first direction indicated by arrow **110**, print head **120** moves back (reciprocating type of movement) in the direction indicated by arrow **146** (Fig. 1B) and each of the nozzles **126** prints respective print line shown as separate pixels (black squares) **130b**. The process continues until the swath bounded by lines of rectangle **122** is filled in. Print head nozzle pitch **P** is lower than the required print resolution **R** and in order to fill print swath bounded by lines of rectangle **122** the printing is performed in a multi pass mode. For the simplicity of explanation the printing resolution **R** is assumed to be equal in both first and second directions. The print head position is shown at the

beginning of a scan/pass and the previous scan/pass is shown in lines and characters having lower density.

[0016] Other numerals on Figures 1A and 1B indicate: **114** is a control computer that controls operation of the printer, **100** and **102** are respectively media supply and receiving rollers, **136** and **138** are motors that provide movement to substrate-receiving roll **102**, and print head **120** respectively; **140** is a linear guide on which print head **120** travels (scans) back and forth; **122'** designates lines of rectangle that bounds print swath printed by print head **120** when it moves back (reciprocating type of movement) in the direction indicated by arrow **146**.

[0017] As illustrated in Fig. 1B the incremental advance of substrate **108** having large dimensions and being flexible is not equal along print head scan path. When pulled or moved by any other moving means, wide size flexible substrate **108** stretches, skews and undergoes other types of distortions. These stretches and skews create visually disturbing banding effects known as printing artifacts shown in Figure 1B.

[0018] Figures 1A and 1B illustrate a certain type of printed swath filling pattern in a multi pass printing mode introduced for exemplary purposes only. Since the relation between the native resolution of a print head and the printing resolution depends on the type of the print head, additional techniques for printed swath filling patterns in a multi pass printing mode exist. Even in cases where the print head resolution is equal to the printing resolution the printing is performed in a multi pass mode since multi pass printing methods contribute to print quality and provide a higher nozzle redundancy level. In multi pass printing different nozzles participate in printing of the same line when scanning the substrate in a reciprocating type of movement.

[0019] Figure 2A is an illustration of an inkjet printer constructed in accordance with the first embodiment and a swath of a printed image printed by the printer. Print head **120** of the inkjet printing apparatus in addition to the capability of moving in the second direction indicated by arrow **124** may be moved in the direction (back and

forth) indicated by arrow **170**. Direction **170** is the direction in which substrate **108** moves and it is generally parallel to the first direction indicated by arrow **110**.

[0020] Mechanism **174** enabling print head **120** movement in the first direction indicated by arrow **170** may be a linear motor, a metal band or a linear guide with a drive screw. The particular shown mechanism **174** is a regular drive screw with a motor. Activation of the print head motor **138** moves print head **120** in the direction indicated by arrow **124** from one edge of substrate **108** to the second edge of substrate **108**. In course of this movement print head **120** ejects ink droplets and prints a swath bounded by lines of rectangle **176**. Each nozzle **126** of print head **120** prints a line of pixels **178a**. In accordance with the first exemplary embodiment of the method for the purpose of filling-in printed swath **176** movement of print head **120** in the first direction replaces the small and not accurate incremental advance of flexible substrate **108**. Figure 2B shows printing of the next swath-filling scan. Substrate **108** remains static in the course of swath filling sequence. For printing pixel(s) **178b** print head **120** was moved in the first direction indicated by arrow **170** on two digits as illustrated on scale **184**. Scale **184** has been introduced for illustration purposes only. Following this print head moves back in the second direction indicated by arrow **146**. Print head **120** movement in the first direction is relatively small and may be performed by rigid and accurate movement means, reducing printing artifacts caused by distortions of wide flexible substrate **108**. Computer **114** distributes the swath filling information to be printed between successive passes. The particular multi pass swath-filling pattern has been shown for exemplary purposes only. Other swath filling patterns are possible.

[0021] Following completion of swath filling wide flexible substrate **108** advances on swath width (**Ws**) in first direction **110** and print head moving mechanism **174** returns print head **120** to the initial position. Other movement sequences where the print head is returned into the initial position for example, in course of the beginning of the next swath filling process, are possible. The division/split of the movement in the first direction between print head **120**, that makes small and accurate incremental movements, and wide flexible substrate **108** that makes coarse, swath wide

movements, significantly reduces banding effects and associated with these movement printing artifacts. Control computer **114** controls the movement of print head **120** and the division/split of movements in the first direction between print head **120** and substrate **108**.

[0022] In accordance with the second exemplary embodiment of the multi pass ink jet printing method shown in Figure 3A, inkjet printing apparatus in addition to print head **120** moving means **174** has image position detection means **180**. Image position detection means **180** may be located along the second printing direction. Generally, image position detection means **180** should be of extended form to cover the whole width of printing substrate **108**. Alternatively, image position detection means **180** may be positioned at predefined locations over substrate **108**. Their position may be fixed or adjustable as appropriate for a particular machine design. Image position detection means **180** include a source of illumination and a detector. The source of illumination may be an incandescent lamp, a LED or a laser diode operating in visible or non-visible range of spectrum. The detector may be a photodiode, a quadrant detector, a CCD, or a video camera type detector. Magnetic detection means may be used also. Control computer **114** controls operation of image position detection means and of all units of the printer.

[0023] For printing, substrate-moving mechanism moves substrate **108** in the first direction indicated by arrow **110**. Print head motor **138** with the help of moving mechanism moves print head **120** in the second direction indicated by arrow **124** from one edge of substrate **108** to the second edge of substrate **108**. In course of this movement print head **120** ejects ink droplets and prints a swath bounded by lines of rectangle **190**. The printing is performed in multi pass mode. Concurrently to printing a print swath of an image print head **120** prints in predefined positions control marks **200** shown, for exemplary purposes only, as crosses. Alternatively, an additional print head may be used to print the marks.

[0024] Following each successive multi pass swath print completion, wide flexible substrate **108** advances on the required distance in the first direction. This advance of

wide flexible substrate **108** is not an accurate one, since deformations introduced into wide flexible substrate are not homogeneous across the width of substrate **108**. Image on substrate position detecting means **180** detect and measure the coordinates of control marks **200**, and communicate the coordinates of control marks **200** to control computer **114**. Control marks **200** are indicators of the image on substrate position (and the position of substrate **108** itself). Control computer **114** uses the coordinates of control marks **200** to calculate the deviation of the current image or pixel position from the previous swath (image) position. Based on the measured current image position deviation control computer **114** calculates the required correction movement of print head **120** with respect to the previously printed swath.

[0025] In the course of print head **120** movement in the second direction indicated by arrow **146** print head moving mechanism **174** may perform continuous (dynamic) corrective movement of print head **120** in the first direction indicated by arrow **170**. The corrective movement of print head **120** compensates for deformations and errors caused by wide format flexible substrate movement and reduces visible banding effects. Scale **184** is introduced for illustration purposes only. It shows the print head position at the beginning and end of the next swath bound by lines of rectangle **198**. In this exemplary case the print head position was adjusted on one digit at the beginning of the scan and on two digits at the end of the scan. The trajectory of the continuous dynamic movement of print head **120** is shown by broken line **202** for illustration purposes only.

[0026] Figure 4A is an illustration of the third exemplary embodiment of inkjet printer and a swath of an image printed by the printer. Ink ejecting nozzles **218** disposed along print head **210** width (W_{ph}) are virtually split into inner section nozzles (**IN**) and peripheral section nozzles (**PER**). In addition to this, the printer has image position detecting means **180** located along the second printing direction. Generally, image position detection means **180** should be of extended form to cover the whole width of printing substrate **108**. Alternatively, image position detection means **180** may be positioned at predefined locations over substrate **108**. Their position may be fixed or adjustable as appropriate for a particular machine design or

type of printing and early detection of control marks. Control computer **114** controls operation of image position detectors **180** and of all units of the printer.

[0027] For printing, substrate-moving mechanism moves substrate **108** in first printing direction indicated by arrow **110**. Print head moving mechanism moves print head **210** in the direction indicated by arrow **124** from one edge of substrate **108** to the second edge of substrate **108**. In course of this movement each nozzle **218** of the inner nozzles section of print head **210** prints a line of pixels **232a** of a swath bounded by lines of rectangle **230**. The printing is performed in multi pass mode. In accordance with the present method concurrently to printing a print swath **230** of an image, print head **210** prints in predefined positions image position control marks **200**. Control marks **200** may be printed on image free areas of the substrate, or on areas of the substrate occupied by an image.

[0028] Following each successive pass print, wide flexible substrate **108** advances on the required small distance in the first direction. This advance of wide flexible substrate **108** is not an accurate one, since deformations introduced into wide flexible substrate are not homogeneous across the width of substrate. In order to compensate for deficiencies of substrate moving mechanism, resulting in banding, image position detecting means **180** detect and measure the coordinates of control marks **200**.

[0029] Image position detecting means **180** communicate the coordinates of image position control marks **200** to control computer **114**. Image position control marks **200** are indicators of the actual image position (and the position of substrate itself). Control computer **114** uses the coordinates of control marks **200** to calculate the deviation of the actual image, or pixel position from the target or desired image position. Based on this deviation control computer **114** calculates the required correction data shift between the inner and peripheral nozzles of print head **210** with respect to the previously printed pass or swath.

[0030] In accordance with the third exemplary embodiment of the method in the course of print head **210** movement in the second direction indicated by arrow **146**

(Fig. 4B) continuous corrective data shift between inner and peripheral sections of nozzles takes place and peripheral nozzles become operative. The shift creates printed image position movement, which is generally parallel to first printing direction **110** and it corrects errors caused by substrate distortion by printing the image in a position adapted to the earlier printed image (swath, pass) position. The continuous corrective data shift compensates for deformations and errors caused by wide format flexible substrate movement and reduces visible banding effects. Figure 4B shows that when print head makes the next scan moving in the direction of arrow **146** and printing pixels **232b** the data shift has involved in printing one peripheral nozzle **236 (PER)** at the beginning of the scan and two peripheral nozzles at the end of the scan as shown by numeral **236** introduced for illustration purposes.

[0031] Practically, the method of multi pass inkjet printing on wide format flexible substrates adapts the geometry and position of the currently printed swath (pass) to the geometry and position of the earlier printed adjacent image swath.

[0032] As illustrated in figures 1 through 4 wide flexible substrates do not deform in a homogeneous way along their width or length and some areas of the printed image may have deformations larger than the others. In order to correct the printing artifacts caused by the non-homogeneous deformation of wide format flexible substrate along the printed swath control marks should be located along and across a printed swath enabling dynamic print head position correction. Control marks **200** may have any shape suitable for machine detection and convenient for deriving, based on the image position detector readings, the new position of flexible substrate **108**. The size of control marks **200** is selected to enable reliable position detection without affecting image quality or content.

[0033] Figures 3 and 4 illustrate exemplary placements and form of control marks **200** along and across printed swaths **190** and **190'**, and **230** and **230'**. When image position control marks **200** are located within the printed image their size and color should be selected in a way that does not create visual effects. This may be done by

digital image analysis of the image that may be made before the swath is printed or concurrently with the swath printing process. The purpose of the analysis is to define proper position locations of image position control marks **200** within printed (image) swaths **190** and **230**.

[0034] Figure 5 shows a simplified control marks **200** position location algorithm. Initially, (block **260**) the digital image to be printed is partitioned into printed swaths and strips of image pertaining to the same swath are defined. Printing is usually performed in four process colors cyan, magenta, yellow and black (CMYK). The proportion of each of the process colors within each of the swaths is different and at block **262** ink coverage or content for a particular printed swath is calculated for each ink. Image position control marks **200** may be printed by a color (ink) that has largest coverage (proportion) in a particular swath. This ink is selected at block **264**. Further to this position control marks printed when print head moves in the direction indicated by arrow **124** may be placed in places that will be overprinted by ink of the same color when print head **120** will move in the direction indicated by arrow **146**. In order to find suitable control marks placement position within the image at block **268** swath with highest ink content is further analyzed for sections having clusters of inked pixels of sufficient size for marks placement.

[0035] Distribution of control marks along and across printed swath or within the printed image in a way that enables relatively smooth continuous print head position control takes place at step **270**. The processed swath is printed simultaneously with image on substrate position control marks at step **272**. The process continues in a similar way for the next swath. Alternatively, an additional print head may print marks **200**.

[0036] Distribution of control marks along and across printed swath in a way that enables relatively smooth continuous print head position control within a single color (ink) may not always be possible. Highlight print areas may have not enough dense clusters for proper control marks positioning. In such extreme cases the control marks may be placed in more than one printing color (ink).

[0037] Alternatively, image position control marks may be printed by transparent ink or ink invisible to human eye, but easy detectable by image position detection means. Such marks may be printed in any location on the substrate and no special image processing is required. Such ink may be a clear ink Crystal UGE-0513 commercially available from Sun Chemicals (Sunjet), Fort Lee, NJ U.S.A. Printing control marks by ink invisible to human eyes requires use of an additional print head. Alternatively, the marks may be printed by magnetic ink.

[0038] Figure 6 shows the fourth exemplary embodiment of the method that provides another way of improvement of the printing accuracy and banding effects reduction. A line type mark **246** may be printed as the first line on image free area providing a reference for image on substrate position detectors operation. First printed swath **242** is aligned to this line. Location of image on substrate position detectors along the scanning path enables simultaneous reading of a large number of image on substrate control marks coordinates and provides means for making a practically smooth print head correction movement.

[0039] Control marks **200** provide an effective tool for image position control. Monitoring the control marks coordinates (and accordingly the substrate position) and moving the print head or shifting the data in the same direction as the substrate moves achieves image position control and corrects printing artifacts caused by substrate distortions. Figure 7A is a schematic illustrations of an inkjet printer constructed in accordance with the fourth exemplary embodiment of the present method. Printer of figure 7A is similar in structure to the printers of figures 1 - 4, except that image position sensors **180** have been replaced by substrate position detection means **280**, which may be optical mouse type sensors such as ADNS – 2051 commercially available from Agilent Technologies, Inc. Palo Alto, CA 94303 U.S.A., or other similar sensors. Substrate position detection means **280** detect substrate distortions, schematically shown by phantom line **284**, and associated with the distortions changes in printed image position. Substrate position detection means **280** are in communication with control computer **114** that receives substrate distortion coordinates and shifts accordingly the data to be printed between the inner nozzles

section and peripheral nozzles section of print head **210** or moves print head **120** in the desired direction. The continuous corrective data shift compensates for deformations and errors caused by wide format flexible substrate movement and reduces visible banding effects.

[0040] Wide format flexible substrate deformations, as shown in figure 7B by phantom lines **284** and **294,** are non-homogeneous along the printed swath. There may be instances in which the edges of substrate **108** are deformed, but central section of substrate **108** marked by phantom line **290** is not deformed. Other types of substrate deformations are possible. A second set of substrate position detection means **280'** disposed in a position allowing monitoring of the lower part of printed swath providing a more accurate correction value and accordingly the shift of data between inner and peripheral nozzles sections of print head **210,** or moving print head **120** in the direction indicated by arrow **170**. A variety of signal processing methods that are per-se not part of the method may be used to process the position signals provided by substrate position detectors **280** and **280'**.

[0041] In an alternative embodiment non-contact substrate position detection means **250** may be replaced by contact substrate position detection means such as metering rollers that are in permanent contact with substrate **108**. Figure 8 shows such a metering roller **280** contacting substrate **108**. In order to avoid any roller slippage the contact surface of roller **300** has an abrasive type coating **304**. Roller **300** typically has certain preload and it may have some type of back support surface **308** that facilitates the metering process.

[0042] The exemplary embodiments illustrate so-called banding artifacts correction between the successive scans within the same print swath and corrections of the banding artifacts between two relatively wide printed swaths. The method is applicable to detection and compensation of missing lines and pixels providing a higher degree of redundancy in multi pass printing without using additional print heads.

[0043] Prints printed by the printer produce images of improved quality, as compared to existing printers. They do not exhibit banding effects. The width of printed substrate may be further increased without damaging print quality.

[0044] The above disclosure is intended as merely exemplary, and not to limit the scope of the invention, which is to be determined by reference to the appended claims.

What is claimed is:

1. An ink jet printing apparatus for printing an image on wide format flexible substrate, comprising: a substrate (**108**) and a mechanism (**136**) for moving the substrate (**108**) in first direction (**110**), a print head (**120, 210**) and a mechanism (**138**) for moving the print head (**120, 210**) in second direction, image position detecting means (**180, 250**) for detecting image on substrate position, and a control computer (**114**), characterized in that errors in said image and substrate (**108**) positions are corrected by adapting the geometry and position of the currently printed swath to the geometry and position of the adjacent earlier printed image swath.

2. The apparatus of claim 1, characterized in that said image and substrate position detecting means (**180** and **250**) measure the currently printed image on substrate position relative to the earlier printed image (swath);

3. The apparatus of claim 1, characterized in that the control computer (**114**) calculates the deviation of the current image on substrate position relative to the previous swath position and generates a correction value;

4. The apparatus of claim 1, characterized in that for correction of said image position error said print head (**120**) is moved in said first (**110, 170**) direction in accordance with said image position correction value;

5. The apparatus of claim 1, characterized in that for correction of said image position error the print data is shifted between inner and peripheral nozzles of said print head (**210**) in said first printing direction (**110, 170**) in accordance with said image position correction value.

6. The apparatus of claim 1, characterized in that said print head (**120, 210**) prints the image position control marks (**200**) concurrently with image printing and said

image position control marks (**200**) define the geometry and position of said printed swath on said substrate (**108**);

7. The apparatus of claim 1, characterized in that said print head (**120, 210**) prints said image position control marks (**200**) concurrently with the image printing and places the image position control marks (**200**) in places consisting of one of a group of image free areas and image areas;

8. The apparatus of claims 1 and 7, characterized in that said control marks (**200**) are printed by ink consisting of one of a group visible ink, invisible ink or magnetic;

9. A method of multi pass inkjet image printing on wide format flexible substrates, comprising moving a substrate (**108**) in first printing direction (**110**) and scanning the substrate (**108**) by reciprocally moving a print head (**120**) in second printing direction (**124, 146**), characterized in that errors in said substrate (**108**) movement are corrected by adapting the geometry and position of the next printed swath to the geometry and position of the adjacent earlier printed image swath.

10. The method of claim 9, characterized in that said geometry and position of the next printed swath is adapted to said geometry and position of the adjacent earlier printed image swath by moving said print head (**120**) in first direction (**170**);

11. The method of claim 9, characterized in that said geometry and position of the next printed swath is adapted to said geometry and position of the adjacent earlier printed image swath by shifting data between the inner and peripheral nozzles of said print head (**210**) in the first direction (**170**);

12. The method of claim 9, characterized in that the coordinates of said control marks (**200**) determine the geometry and position of the image;

13. The method of claim 9, characterized in that said image position detecting means (**180**) measure the image and substrate position;

14. The method of claim 9, characterized in that said control computer (**114**) calculates the deviation of the current image on substrate position from the adjacent earlier printed image on substrate position and generates the correction value;

15. A method of multi pass inkjet printing on wide format flexible substrate, characterized in that distortions of the geometry of a wide format flexible substrate (**108**) are compensated by adapting the geometry and position of the printed swath to the geometry and position of the adjacent earlier printed image swath.

16. A method of multi pass inkjet printing on wide format flexible substrate, characterized in that distortions of the geometry of a wide format flexible substrate (**108**) are compensated by distributing the movement in one direction between the print head (**120**) that performs small and accurate movements and flexible substrate (**108**) that performs coarse movement.

17. An ink jet printing apparatus for printing an image on wide format flexible substrates, comprising: a substrate (**108**) and a mechanism (**136**) for moving the substrate (**108**) in first direction (**110**), a print head (**120**), a mechanism (**138**) for moving the print head (**120**) in second direction, position detecting means (**180**) for detecting actual image and substrate position and control computer (**114**), characterized in that said print head makes small incremental movement in said first direction and errors in said substrate (**108**) position are corrected by dividing the movement in said first direction between coarse movement performed by said substrate (**108**) and accurate movement of said print head (**120**).

18. The apparatus of claim 17, characterized in that said image position detecting means (**180**) measure the image on substrate position relative to the adjacent earlier printed image;

19. The apparatus of claim 17, characterized in that said image position detecting means (180) are one of a group of electr-optical, magnetic or contact roller means;

20. The apparatus of claim 17, characterized in that the control computer (**114**) calculates the deviation of the printed image swath relative to the previously printed swath and generates a correction value;

21. The apparatus of claim 17, characterized in that for correction of said substrate (**108**) position error said print head (**120**) is moved in said first printing (**110, 170**) direction in accordance with said swath position correction value.

22. The apparatus of claim 17, characterized in that said print head (**120**) prints the image position control marks (**200**) concurrently with image printing and said marks (**200**) define the geometry and position of said printed swath on said substrate (**108**);

23. The apparatus of claims 17 and 21, characterized in that said control marks (**200**) are printed by ink consisting of one of a group visible ink or invisible ink;

24. An ink jet printing apparatus for printing an image on wide format flexible substrates, comprising: a substrate (**108**) moving in first direction (**110**) and a print head (**120**) moving in second direction (**124, 146**), characterized in that said print head is capable of making small incremental movements in said first direction (**170**) and errors in said substrate (**108**) movement are corrected by dividing the movement in said first direction between coarse movement performed by said substrate (**108**) and accurate movement of said print head (**120**).

25. A method of multi pass inkjet printing on wide format flexible substrates, characterized in that distortions of the geometry of a wide format flexible substrate (**108**) are compensated by distributing the movement in one direction between the flexible substrate (**108**) that performs coarse movement and shift of the data to be printed between inner and outer groups of nozzles equivalent to the small and accurate movement by the print head.

26. A method of multi pass inkjet printing on wide format flexible substrate, characterized in that distortions of the geometry of a wide format flexible substrate (**108**) are compensated by distributing the movement in the first direction between flexible substrate (**108**) that performs coarse movement and the print head (**120**) that performs small and accurate movements in the same direction and concurrently moves in the second direction.

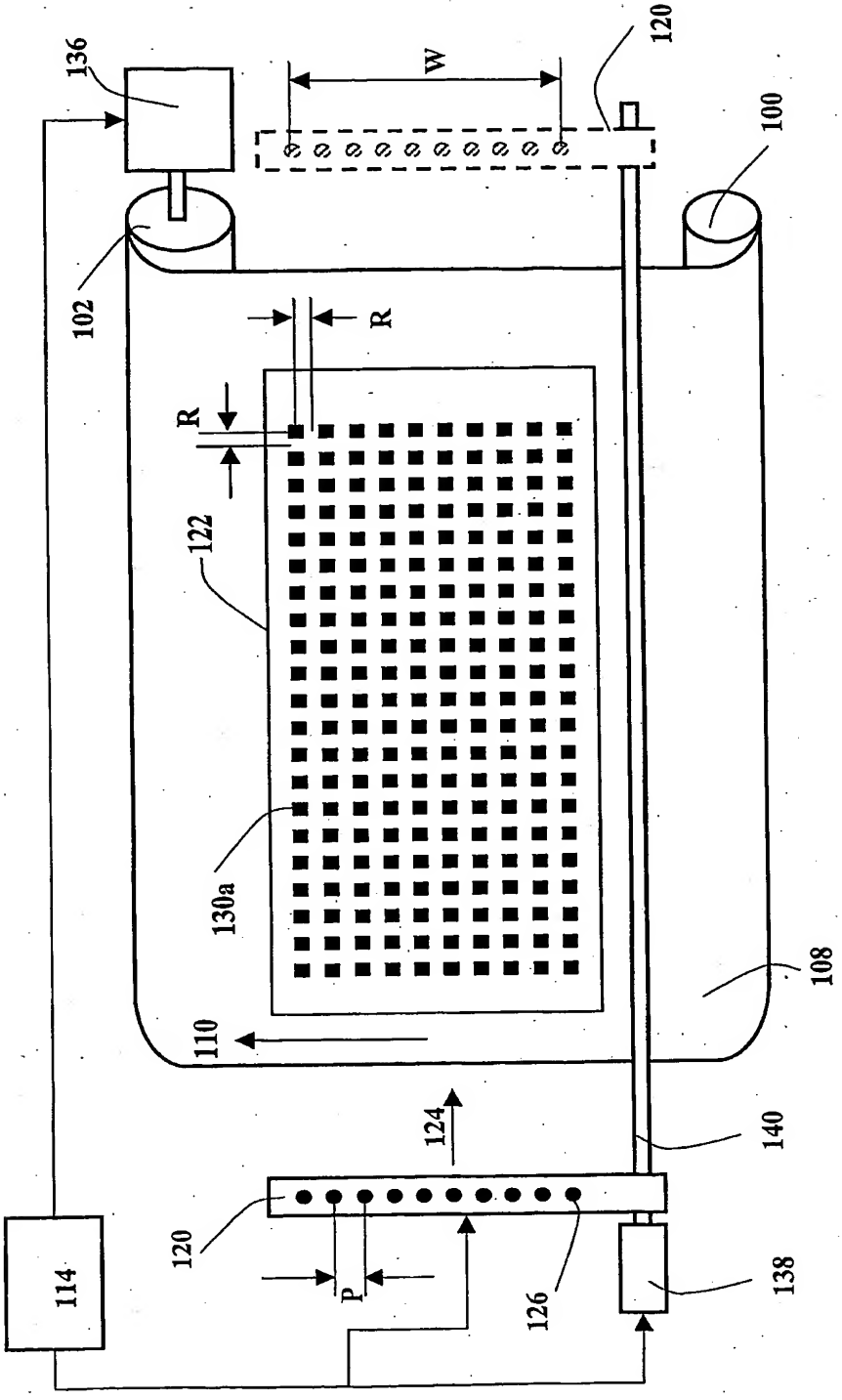

FIG. 1A

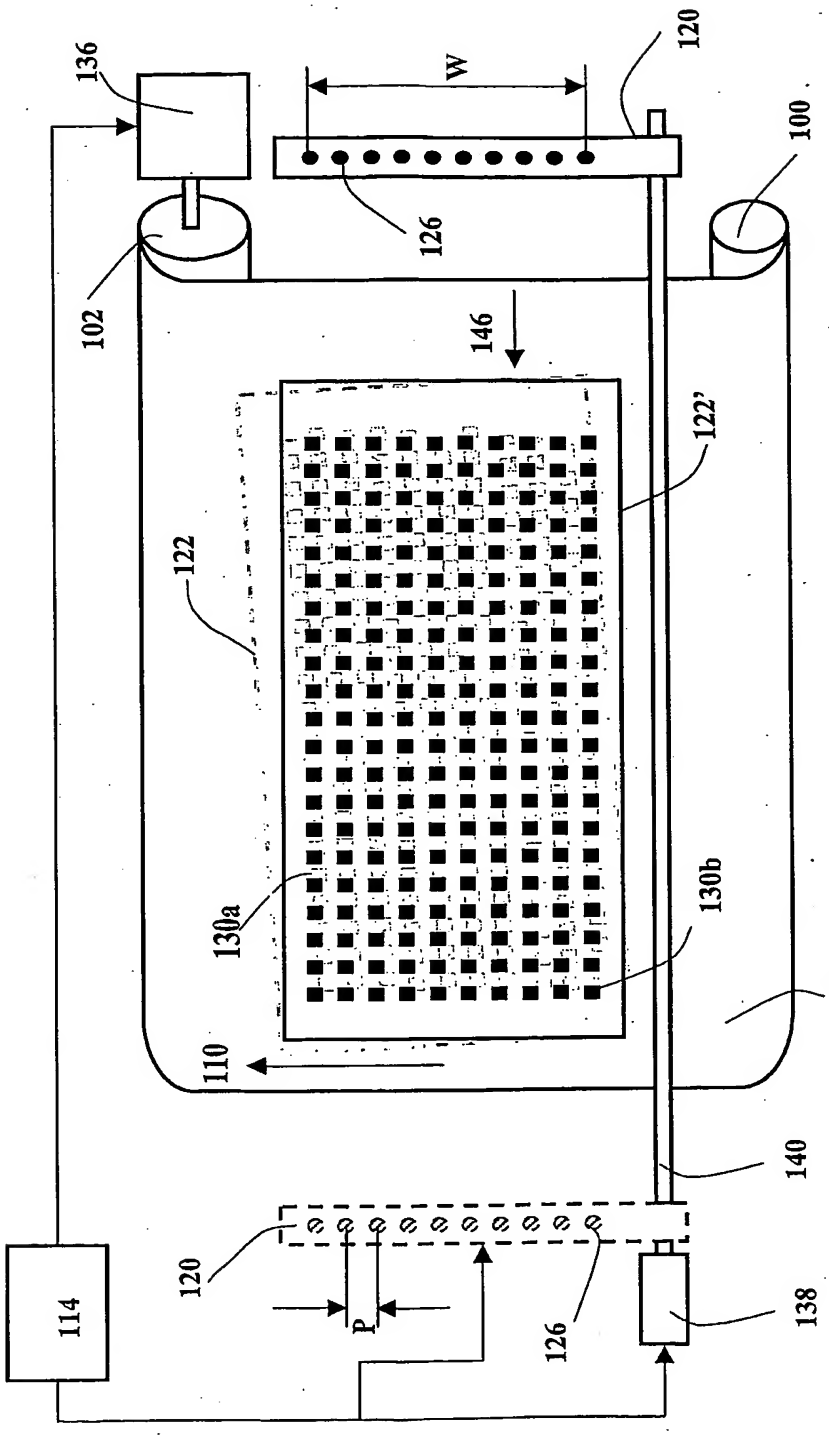
136
W
120
100
126
102
146
122'
122
130a
130b
108
110
140
120
P
126
138
114

FIG. 1B

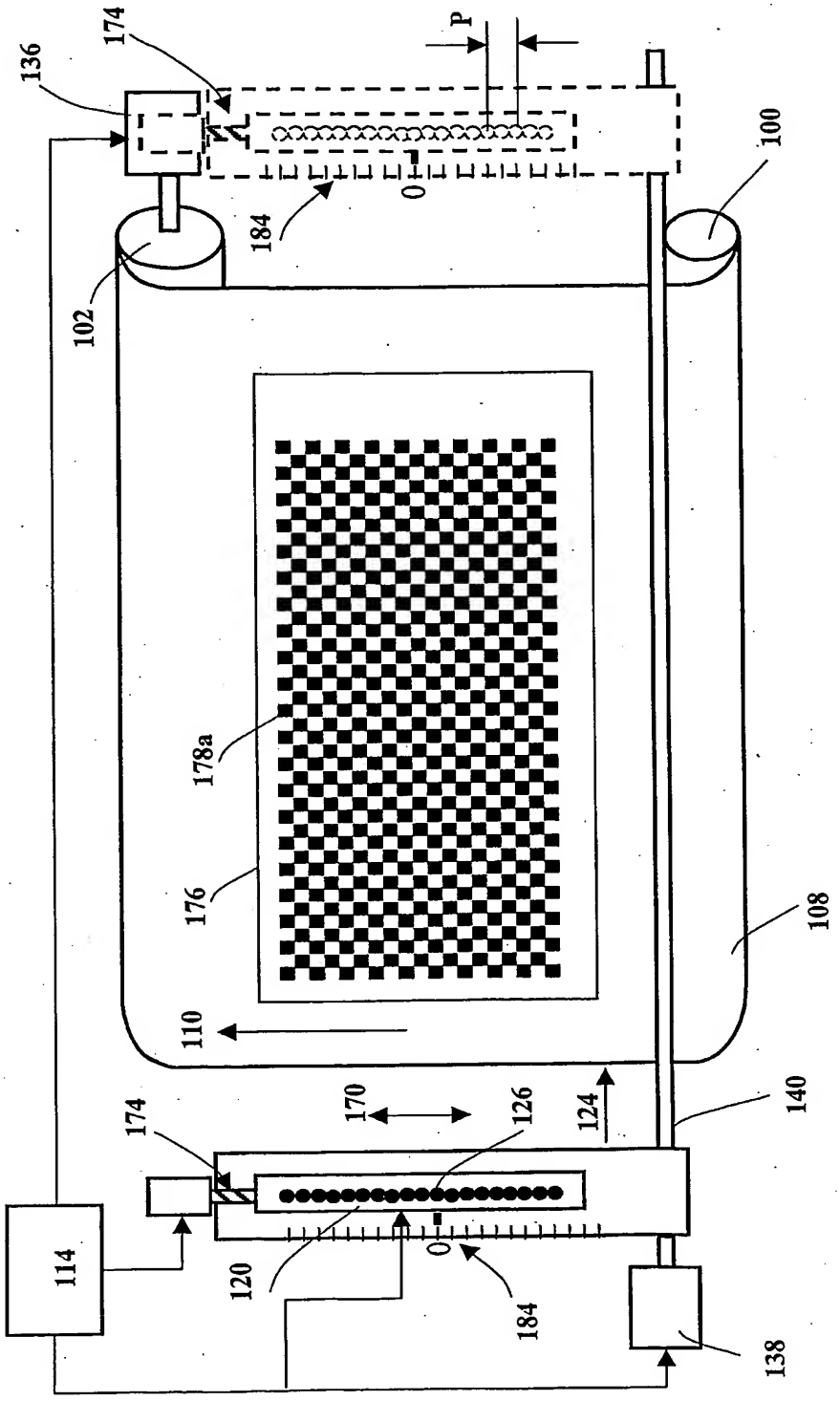
P
174
136
100
184
102
178a
176
108
110
170
126
124
140
174
114
120
184
138

FIG. 2A

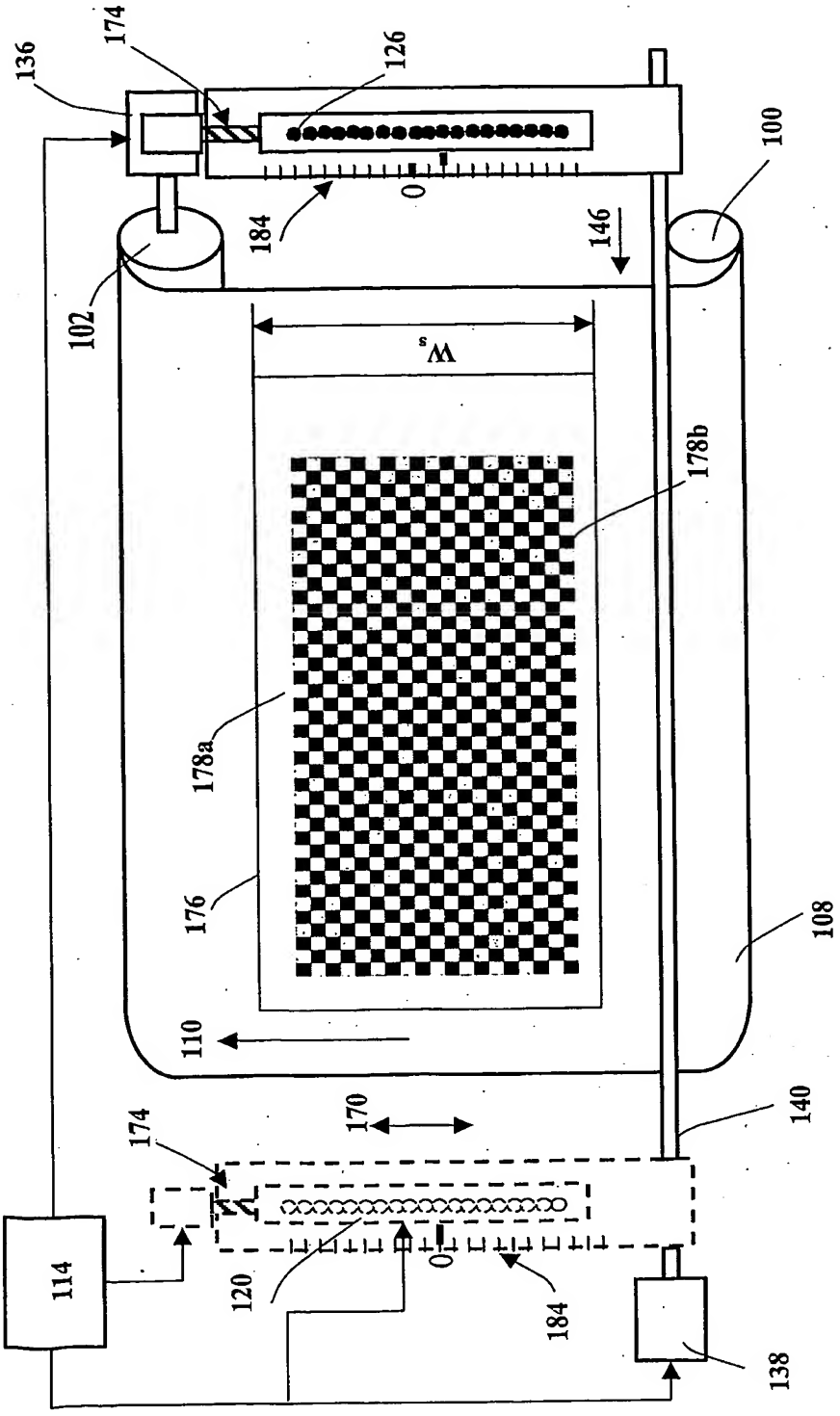
136
174
126
100
184
0
146
102
W_s
178b
178a
176
108
110
170
140
174
114
120
184
138

FIG. 2B

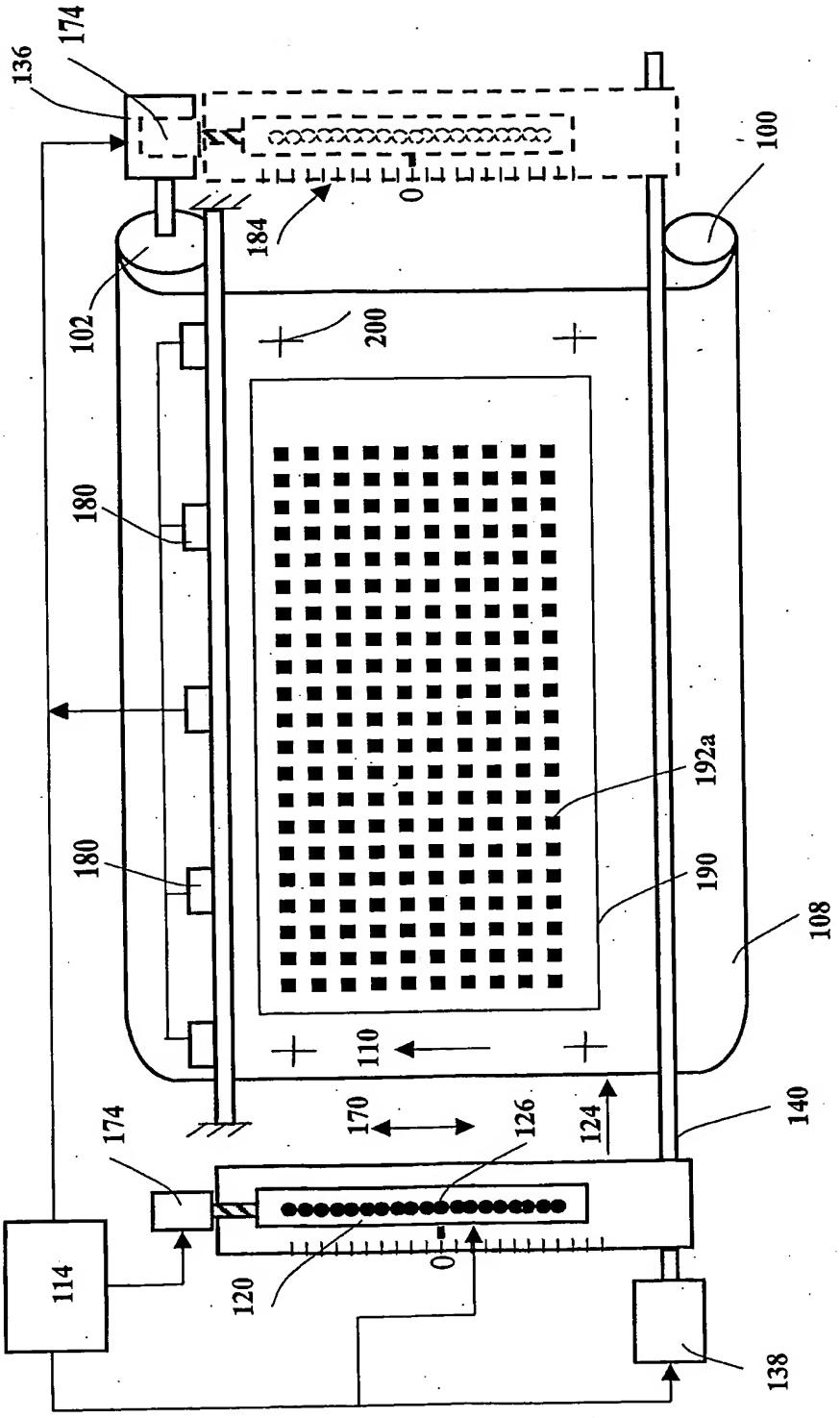
174
136
100
184
102
200
180
180
192a
190
108
110
170
126
124
174
140
114
120
138

FIG. 3A

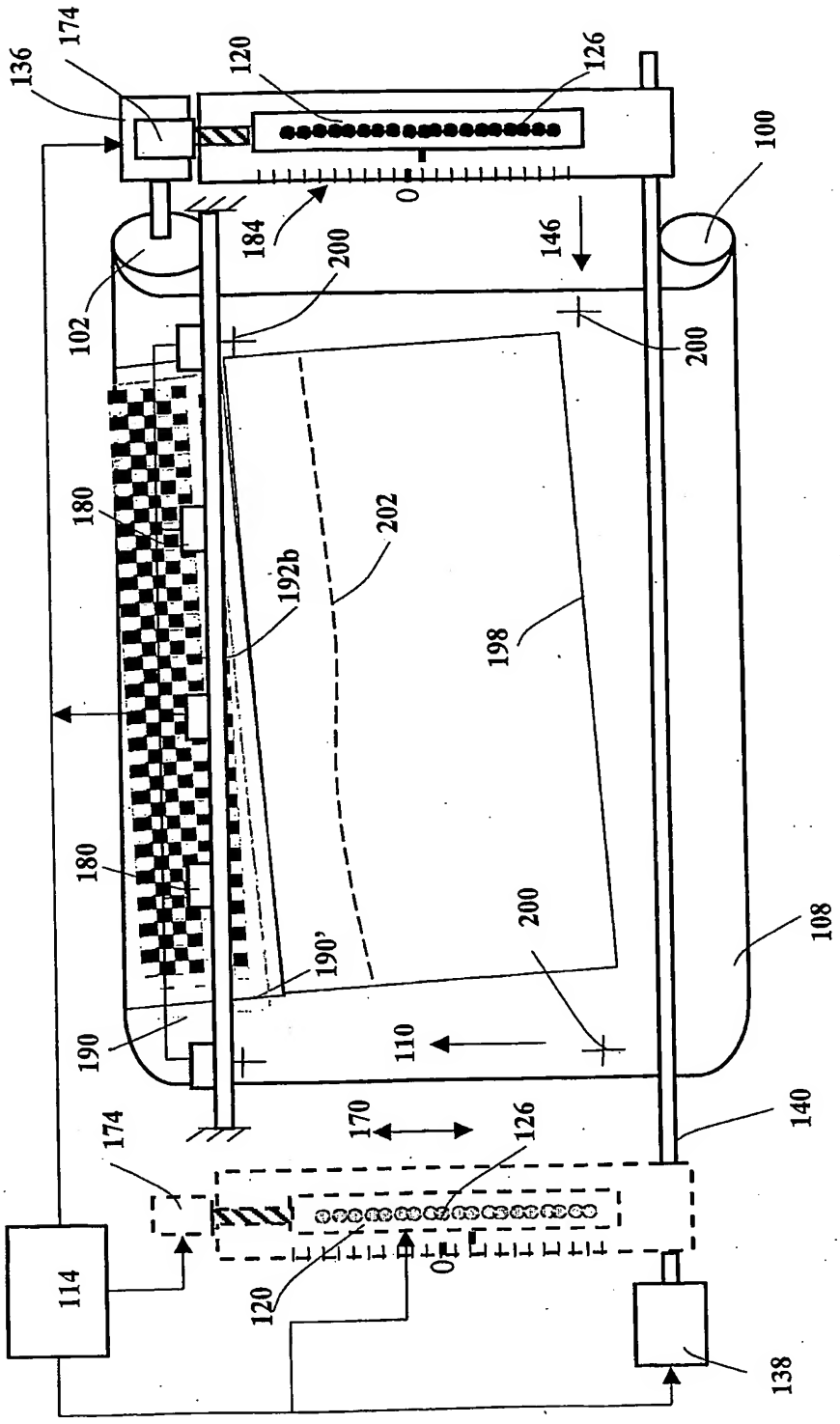
136
174
120
126
100
184
200
146
102
200
200
180
202
192b
198
180
190'
200
108
190
110
174
170
126
140
114
120
138

FIG. 3B

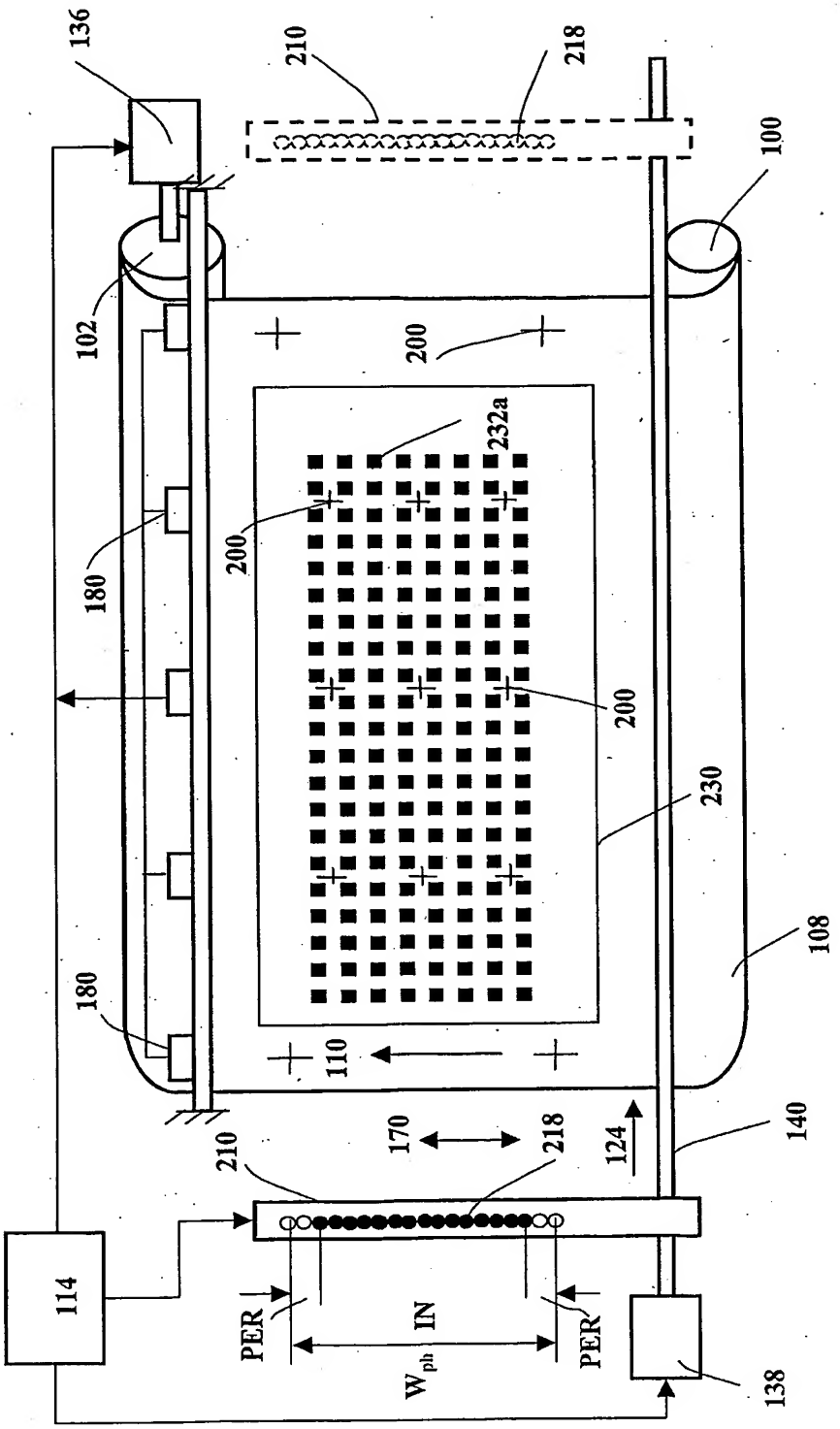
136
210
218
100
102
200
232a
180
200
200
230
108
180
110
170
218
124
140
210
114
PER
IN
PER
W_{ph}
138

FIG. 4A

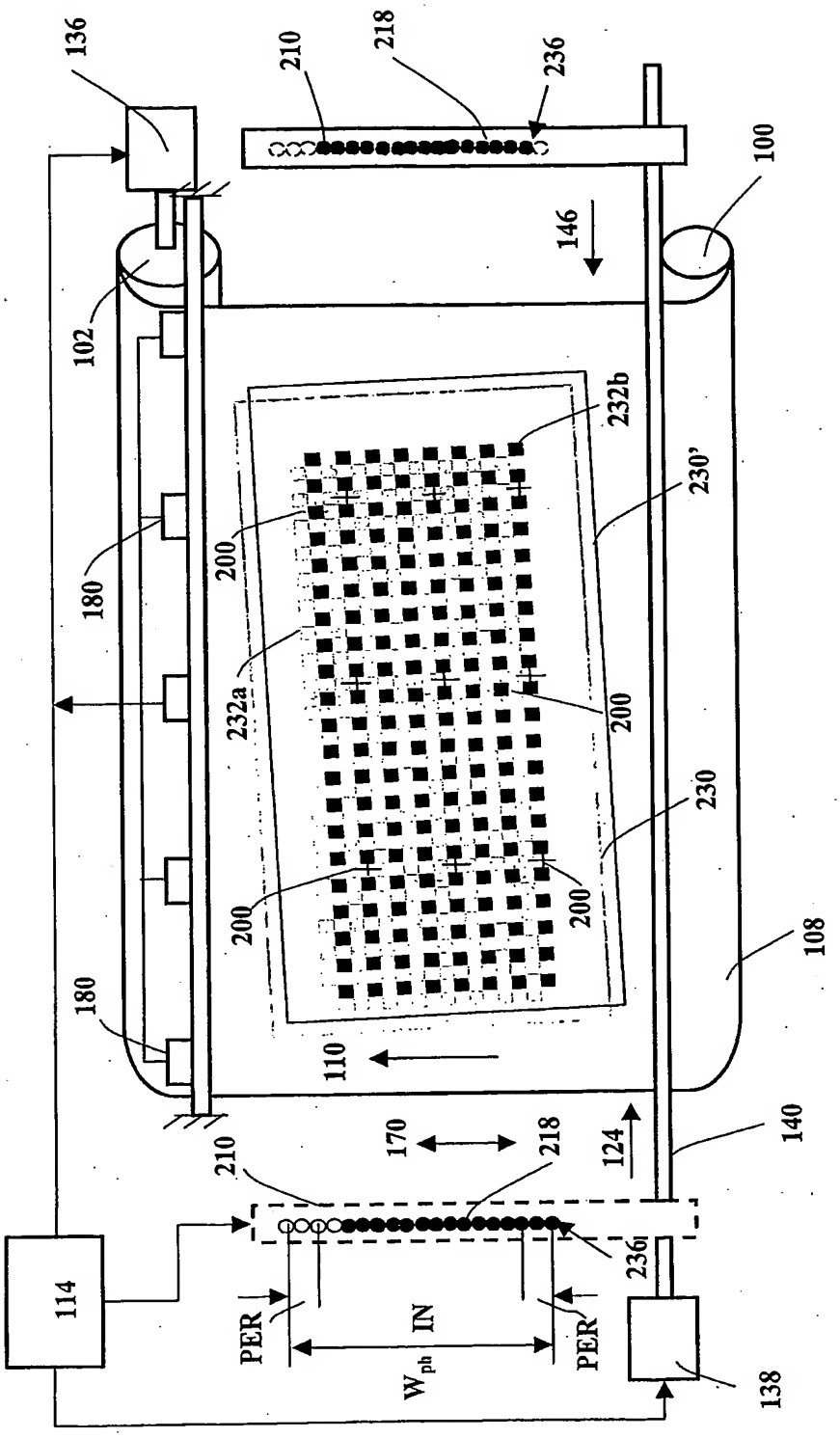
136
210
218
236
100
146
102
232b
230'
180
200
232a
200
230
200
200
180
108
110
170
218
124
140
210
236
114
PER
IN
PER
W_{ph}
138

FIG. 4B

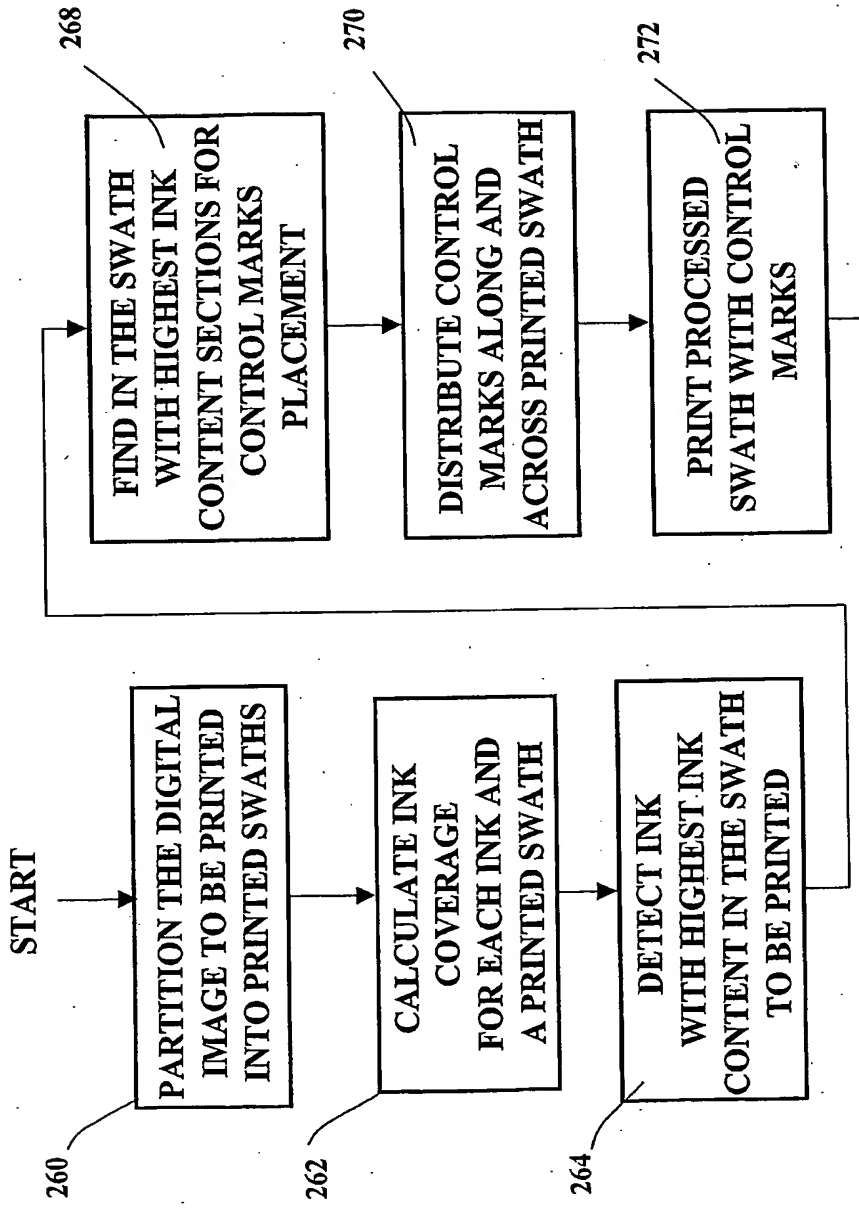
START
PARTITION THE DIGITAL IMAGE TO BE PRINTED INTO PRINTED SWATHS
260
CALCULATE INK COVERAGE FOR EACH INK AND A PRINTED SWATH
262
DETECT INK WITH HIGHEST INK CONTENT IN THE SWATH TO BE PRINTED
264
FIND IN THE SWATH WITH HIGHEST INK CONTENT SECTIONS FOR CONTROL MARKS PLACEMENT
268
DISTRIBUTE CONTROL MARKS ALONG AND ACROSS PRINTED SWATH
270
PRINT PROCESSED SWATH WITH CONTROL MARKS
272
PROCEDE TO THE NEXT SWATH

FIG. 5

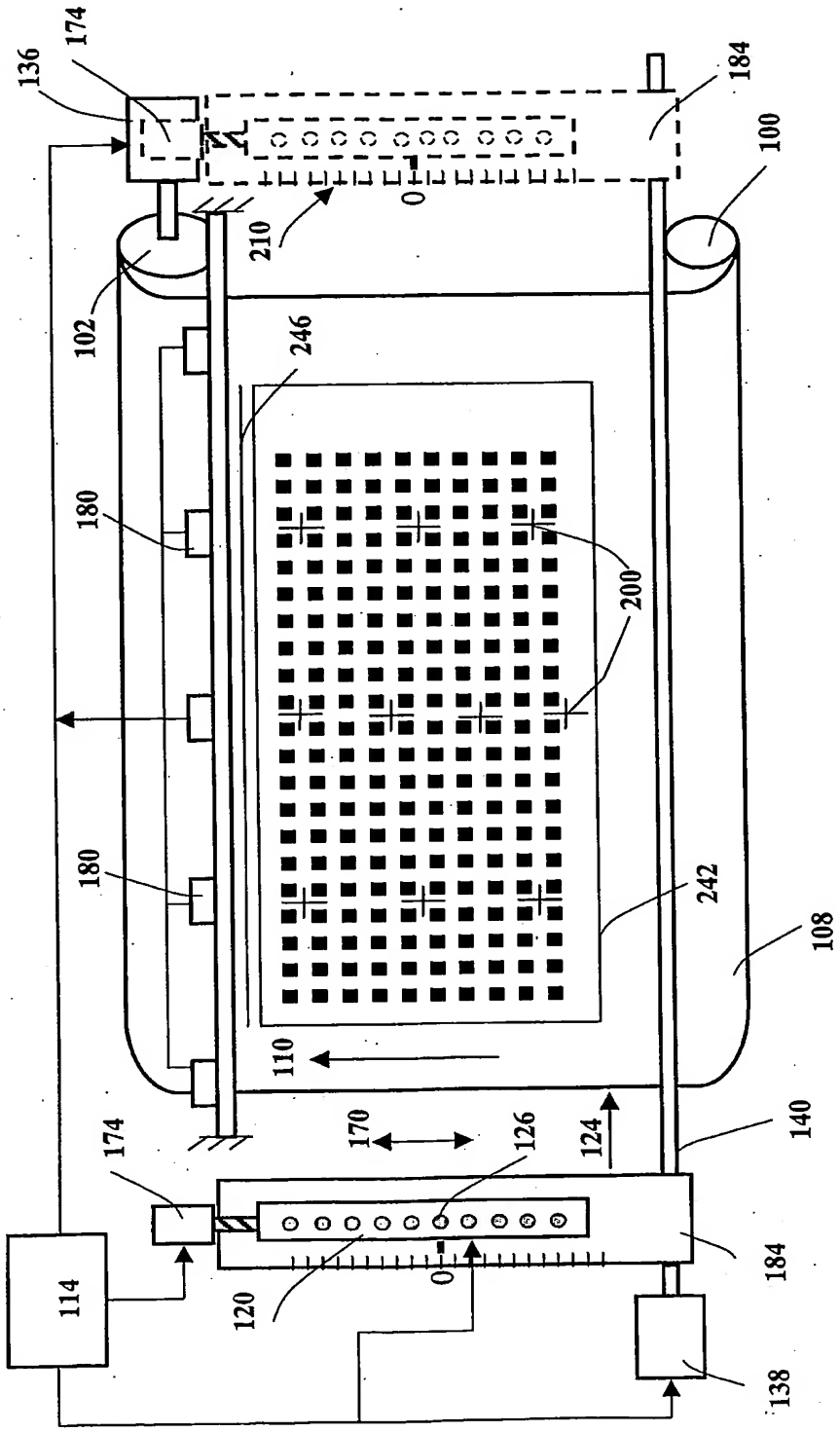
136
174
184
100
210
102
246
180
200
180
242
108
110
174
170
126
124
140
184
114
120
138

FIG. 6

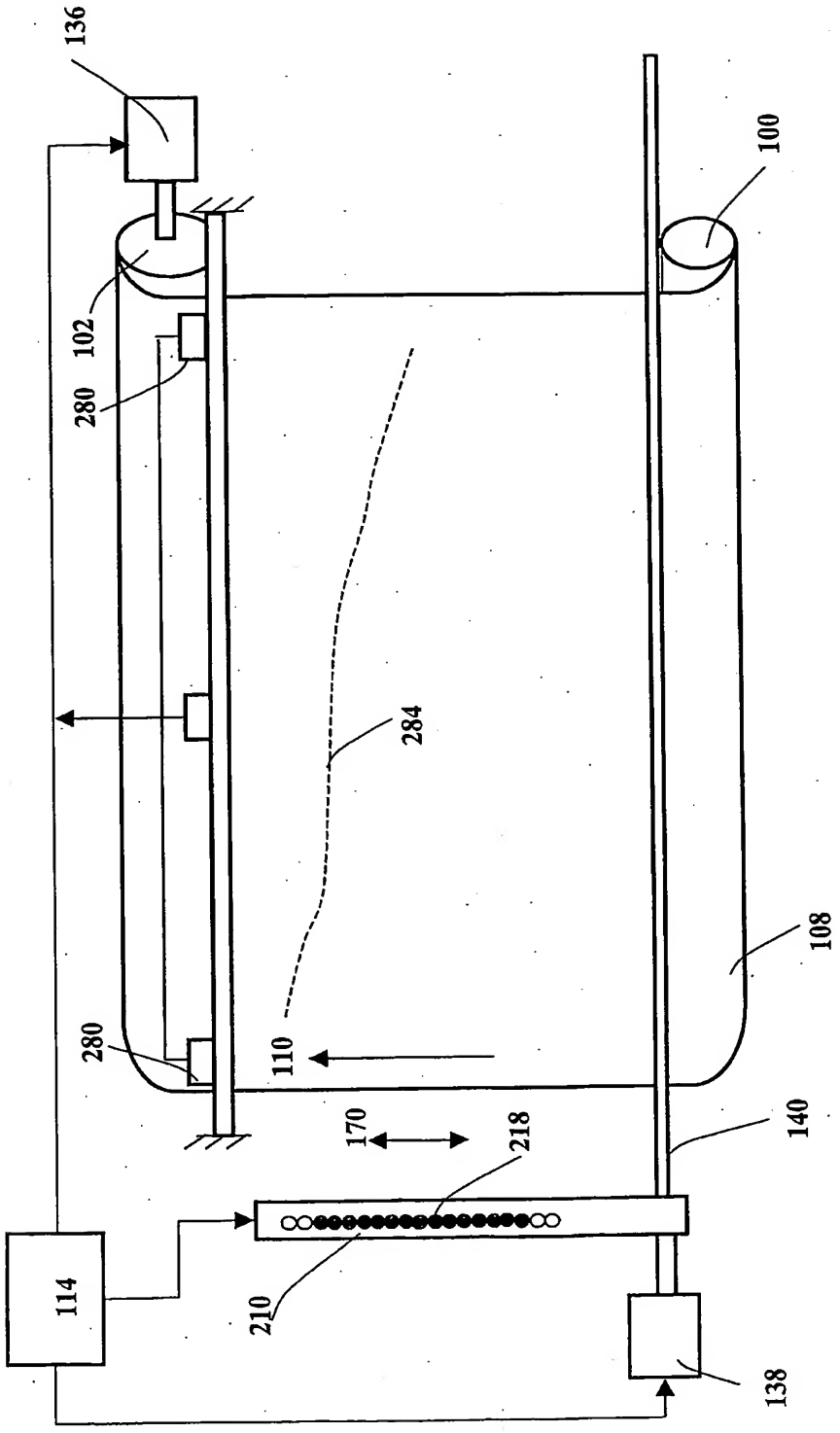

FIG. 7A

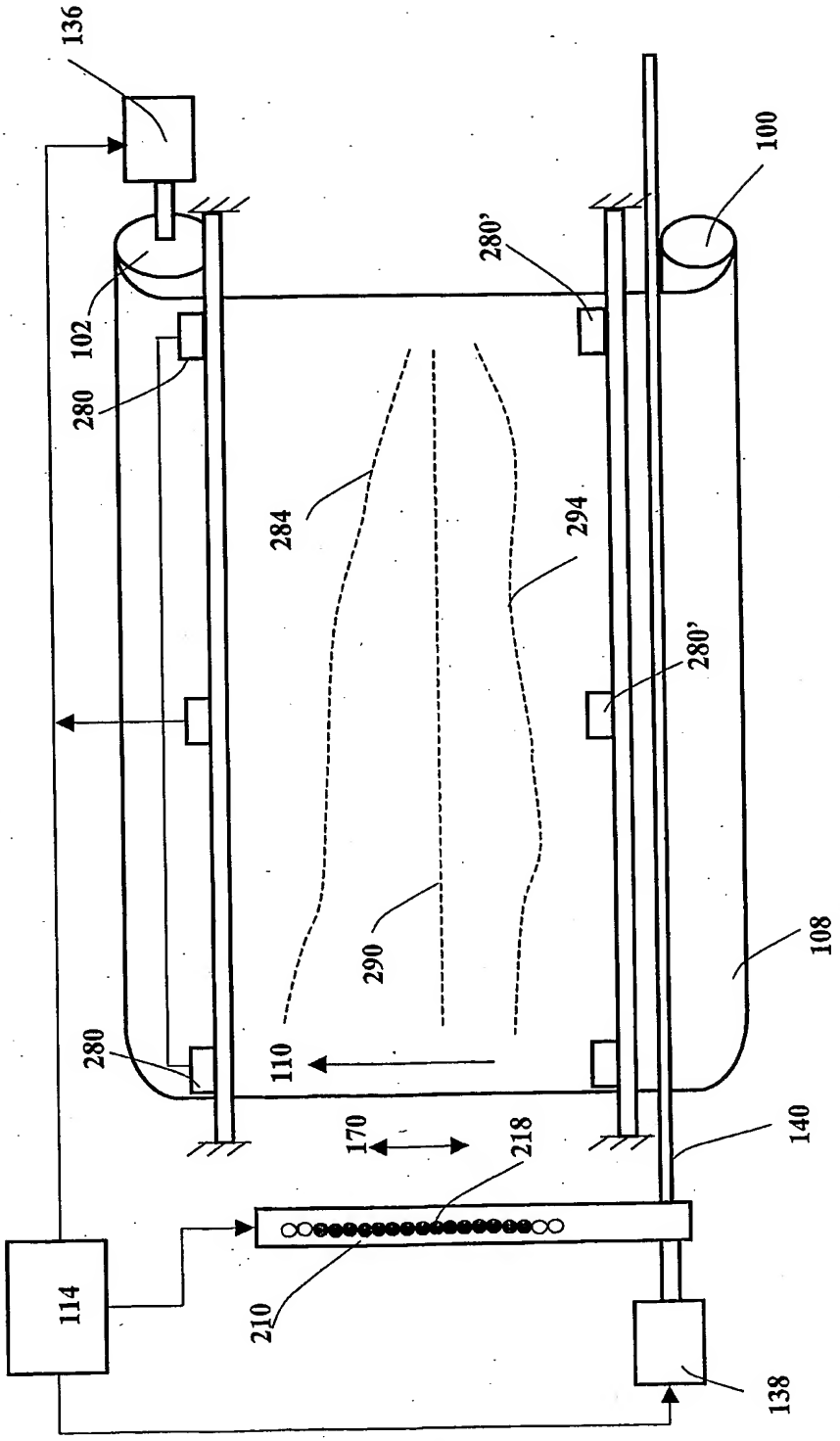
136
100
280'
102
280
284
294
280'
290
108
280
110
170
218
140
114
210
138

FIG. 7B

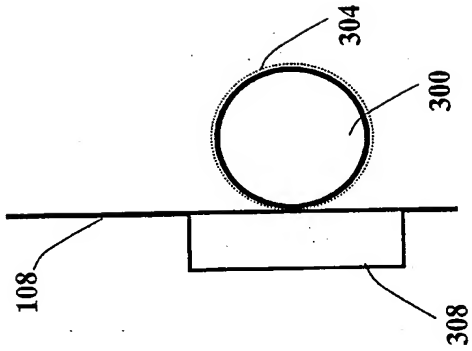

FIG. 8

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

PCT

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13 October 2005 (13.10.2005)

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(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
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161210 1 April 2004 (01.04.2004) IL

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(75) Inventors/Applicants *(for US only)*: **KOREM, Aharon** [IL/IL]; 2 Ayelet Chen, Apt. 13, 46370 Hertzlia (IL). **DVORI, Yaron** [IL/IL]; 39 Tabenkin Street, 53620 Givataim (IL). **YAKUBOV, Igor** [IL/IL]; 113 Bar Kochba Street, 46370 Hertzlia (IL). **GANI, Arnon** [IL/IL]; 7 Hamifras Street, Apt. 1., 70800 Gan Yavne (IL).

(74) Agent: **SANFORD T.COLB & CO.**; P.O. Box 2273, Rehovot 76122 (IL).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

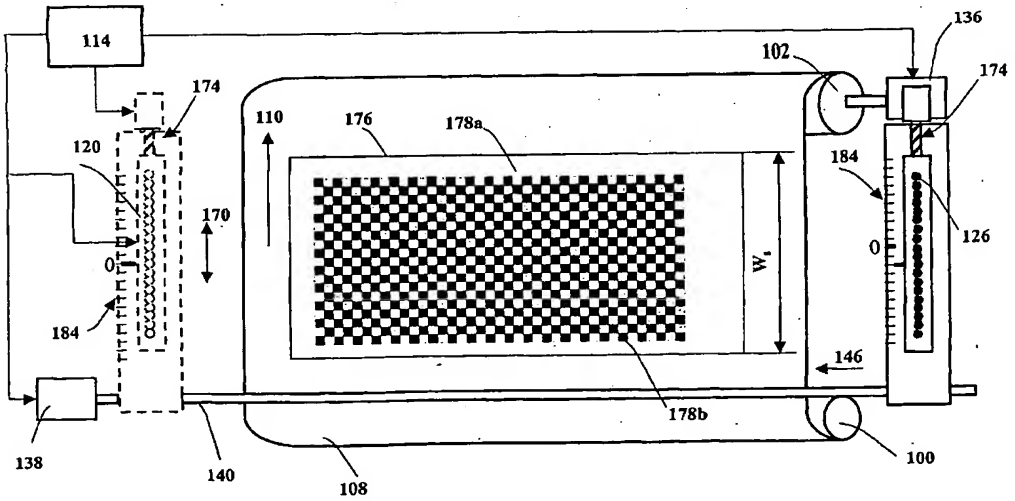
(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

(88) Date of publication of the international search report:
14 December 2006

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: A METHOD OF PRINTING ON LARGE FORMAT FLEXIBLE SUBSTRATE AND PRINTING APPARATUS



(57) Abstract: The present invention discloses a method of multi pass inkjet printing (120) on wide format flexible substrates (108) where errors in flexible substrate positions are corrected by adapting the geometry (190) and position of the next printed swath to the geometry (190) of the adjacent earlier printed image swath.

WO 2005/094170 A3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL05/00326

A. CLASSIFICATION OF SUBJECT MATTER
IPC: B41J 2/15(2006.01)

USPC: 347/12,14,16,19,41
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 347/12, 14, 16, 19, 41

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2006/0087529 A1 (Tayuki) 27 April 2006 (27.04.2006), columns 2-5	1-26
A	US 6,532,026 B2 (Takahashi et al.) 11 March 2003 (11.03.2003)	1-26

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
23 August 2006 (23.08.2006)

Date of mailing of the international search report
02 OCT 2006

Name and mailing address of the ISA/US
Mail Stop PCT, Attn: ISA/US
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
Facsimile No. (571) 273-3201

Authorized officer
Lamson Nguyen

Telephone No. 571-272-2259

Form PCT/ISA/210 (second sheet) (April 2005)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY
(Chapter I of the Patent Cooperation Treaty)

(PCT Rule 44*bis*)

Applicant's or agent's file reference Doc 107-110	**FOR FURTHER ACTION**	See item 4 below
International application No. PCT/IL2005/000326	International filing date *(day/month/year)* 23 March 2005 (23.03.2005)	Priority date *(day/month/year)* 01 April 2004 (01.04.2004)
International Patent Classification (8th edition unless older edition indicated) See relevant information in Form PCT/ISA/237		
Applicant HEWLETT PACKARD INDUSTRIAL PRINTING LTD.		

1. This international preliminary report on patentability (Chapter I) is issued by the International Bureau on behalf of the International Searching Authority under Rule 44 *bis*.1(a).

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

   In the attached sheets, any reference to the written opinion of the International Searching Authority should be read as a reference to the international preliminary report on patentability (Chapter I) instead.

3. This report contains indications relating to the following items:

☒	Box No. I	Basis of the report
☐	Box No. II	Priority
☐	Box No. III	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
☐	Box No. IV	Lack of unity of invention
☒	Box No. V	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
☐	Box No. VI	Certain documents cited
☐	Box No. VII	Certain defects in the international application
☐	Box No. VIII	Certain observations on the international application

4. The International Bureau will communicate this report to designated Offices in accordance with Rules 44*bis*.3(c) and 93*bis*.1 but not, except where the applicant makes an express request under Article 23(2), before the expiration of 30 months from the priority date (Rule 44*bis* .2).

	Date of issuance of this report 14 November 2006 (14.11.2006)
The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No. +41 22 338 82 70	Authorized officer Simin Baharlou e-mail: pt09@wipo.int

Form PCT/IB/373 (January 2004)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
RAFI BRONSTEIN
C/O SCITEX VISION LTD.
5C HATZORAN STREET
P.O. BOX 8743; NEW INDUSTIRAL AREA
NETANYA, ISRAEL 42505

PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing (*day/month/year*)	02 OCT 2006
Applicant's or agent's file reference DOC 107-110	FOR FURTHER ACTION See paragraph 2 below

International application No.	International filing date (*day/month/year*)	Priority date (*day/month/year*)
PCT/IL05/00326	23 March 2005 (23.03.2005)	01 April 2004 (01.04.2004)

International Patent Classification (IPC) or both national classification and IPC

IPC: B41J 2/15(2006.01)
USPC: 347/14,16,41,15

Applicant

SCITEX VISION LTD.

1. This opinion contains indications relating to the following items:

- [X] Box No. I Basis of the opinion
- [ ] Box No. II Priority
- [ ] Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- [ ] Box No. IV Lack of unity of invention
- [X] Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- [ ] Box No. VI Certain documents cited
- [ ] Box No. VII Certain defects in the international application
- [ ] Box No. VIII Certain observations on the international application

2. FURTHER ACTION

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(*b*) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA/ US	Date of completion of this opinion	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	23 August 2006 (23.08.2006)	Lamson Nguyen Telephone No. 703-308-1134

Form PCT/ISA/237 (cover sheet) (April 2005)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/IL05/00326

Box No. I Basis of this opinion

1. With regard to the language, this opinion has been established on the basis of:

☒ the international application in the language in which it was filed

☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. With regard to any nucleotide and/or amino acid sequence disclosed in the international application and necessary to the claimed invention, this opinion has been established on the basis of:

a. type of material

☐ a sequence listing

☐ table(s) related to the sequence listing

b. format of material

☐ on paper

☐ in electronic form

c. time of filing/furnishing

☐ contained in the international application as filed.

☐ filed together with the international application in electronic form.

☐ furnished subsequently to this Authority for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table(s) relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/IL05/00326

Box No. V Reasoned statement under Rule 43 *bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims 1-26	YES
	Claims NONE	NO
Inventive step (IS)	Claims NONE	YES
	Claims NONE	NO
Industrial applicability (IA)	Claims NONE	YES
	Claims NONE	NO

2. Citations and explanations:

Claims 1-26 meet the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest an inkjet printer comprising image position detecting means for detecting image on substrate position, and a control computer, characterized in that errors in said image and substrate positions are corrected by adapting the geometry and position of the currently printed swath to the geometry and position of the adjacent earlier printed image swath.

Claims 1-26 meet the criteria set out in PCT Article 33(4), and thus the claims meet industrial applicability because the subject matter claimed can be made or used in industry.

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
RAFI BRONSTEIN
C/O SCITEX VISION LTD.
5C HATZORAN STREET
P.O. BOX 8743; NEW INDUSTIRAL AREA
NETANYA, ISRAEL 42505

PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing (*day/month/year*)	02 OCT 2006
Applicant's or agent's file reference DOC 107-110	FOR FURTHER ACTION See paragraph 2 below

International application No.	International filing date (*day/month/year*)	Priority date (*day/month/year*)
PCT/IL05/00326	23 March 2005 (23.03.2005)	01 April 2004 (01.04.2004)

International Patent Classification (IPC) or both national classification and IPC

IPC: B41J 2/15(2006.01)
USPC: 347/14,16,41,15

Applicant

SCITEX VISION LTD.

1. This opinion contains indications relating to the following items:

- ☒ Box No. I — Basis of the opinion
- ☐ Box No. II — Priority
- ☐ Box No. III — Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV — Lack of unity of invention
- ☒ Box No. V — Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI — Certain documents cited
- ☐ Box No. VII — Certain defects in the international application
- ☐ Box No. VIII — Certain observations on the international application

2. FURTHER ACTION

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(*b*) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA/ US	Date of completion of this opinion	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	23 August 2006 (23.08.2006)	Lamson Nguyen Telephone No. 703-308-1134

Form PCT/ISA/237 (cover sheet) (April 2005)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/IL05/00326

Box No. I Basis of this opinion

1. With regard to the language, this opinion has been established on the basis of:

☒ the international application in the language in which it was filed

☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. With regard to any nucleotide and/or amino acid sequence disclosed in the international application and necessary to the claimed invention, this opinion has been established on the basis of:

a. type of material

☐ a sequence listing

☐ table(s) related to the sequence listing

b. format of material

☐ on paper

☐ in electronic form

c. time of filing/furnishing

☐ contained in the international application as filed.

☐ filed together with the international application in electronic form.

☐ furnished subsequently to this Authority for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table(s) relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/IL05/00326

Box No. V Reasoned statement under Rule 43 *bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims 1-26	YES
	Claims NONE	NO
Inventive step (IS)	Claims NONE	YES
	Claims NONE	NO
Industrial applicability (IA)	Claims NONE	YES
	Claims NONE	NO

2. Citations and explanations:

Claims 1-26 meet the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest an inkjet printer comprising image position detecting means for detecting image on substrate position, and a control computer, characterized in that errors in said image and substrate positions are corrected by adapting the geometry and position of the currently printed swath to the geometry and position of the adjacent earlier printed image swath.

Claims 1-26 meet the criteria set out in PCT Article 33(4), and thus the claims meet industrial applicability because the subject matter claimed can be made or used in industry.

Document made available under the Patent Cooperation Treaty (PCT)

International application number: PCT/IL05/000326

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A METHOD OF PRINTING ON LARGE FORMAT FLEXIBLE SUBSTRATE AND PRINTING APPARATUS (English)

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חתימת המבקש
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ABSTARCT OF THE INVENTION

The present invention discloses a method of multi pass inkjet printing on wide format flexible substrates where errors in flexible substrate positions are corrected by adapting the geometry and position of the next printed swath to the geometry of the adjacent earlier printed image swath.

In both print head constructions there are nozzles positioned in the inner parts of the print head, or closer to the center of the print head and peripheral nozzles, which are closer to the edges of the print head.

APPLICATION FOR PATENT

Title: A METHOD OF PRINTING ON LARGE FORMAT FLEXIBLE SUBSTRATE AND PRINTING APPARATUS

FIELD OF THE INVENTION

[0001] The present invention relates to the field of inkjet printing and particularly to printing on large format flexible substrates.

BACKGROUND OF THE INVENTION

[0002] Inkjet printing has gained popularity in a number of applications. One of the growing printing applications is printing of billboards, banners and point of sale displays. The ink-jet printing process involves manipulation of drops of ink ejected from an orifice or a number of orifices of a print head onto an adjacent print substrate. Paper, vinyl, textiles, fabrics, and others are examples of print substrates. An ink-jet print head consists of an array or a matrix of ink nozzles, with each nozzle selectively ejecting ink droplets. In both print head constructions the ink ejecting nozzles are usually equidistantly distributed along the width (length) of the print head. A given nozzle of the print head ejects the droplet in a predefined print position on the substrate. An assembly of the adjacently positioned on the substrate ink droplets creates a predetermined print pattern or image. Relative movement between the substrate and the print head enables substrate coverage and image creation. Each ink droplet comprises a picture element, or "pixel." Good print quality requires printing resolution higher that 600 pixel per inch. A typical pitch of an array of nozzles is however 180 or less nozzles per inch.

[0003] To produce the relative movement enabling image creation the substrate moves in one direction termed first direction, and print head moves in another direction termed second direction. The second direction is usually orthogonal to the first direction. Generally, the print head has less weight and is much smaller in size than substrate. It is convenient to move print head fast over the substrate in a type of reciprocating movement. Each successive reciprocating scan by such a print head in

the second direction creates a relatively wide ink-marked strip or printed swath. The substrate is advancing periodically or simultaneously in the second direction.

[0004] In order to cover the substrate with the desired print resolution of for example 720 pixel per inch a single print head with nozzle pitch of 180 nozzles per inch has to scan in a reciprocating type of movement the print swath four times. Each scan is may be distant from the previous one on 1/720 of inch. The data to be printed is divided accordingly between the scans. This type of printing is called multi pass printing mode. Alternatively for printing at 720 pixels per inch resolution four print heads with nozzle pitch of 180 nozzles per inch may be organized on a common mechanical structure shifted one with respect to the other on a 1/720 of an inch. Organized in this manner print heads may print the desired image in a single pass printing mode, providing better ink coverage and creating more vivid colors. The cost of such print head structure is however too high for regular commercial use. Common structures with print heads shifted one with respect to the other on a fraction of a print head dimension (staggered) are also known in the art.

[0005] Recently inkjet print heads such as XAAR Leopard having nozzle pitch of 300 nozzles per inch and commercially available from XAAR Plc., Cambridge, UK and MAGIC having nozzle pitch of 600 nozzles per inch and commercially available from Scitex Vision Ltd., Netanya, Israel have appeared on the market. Although these print heads have nozzle pitch suitable for high quality printing the printing itself is performed in multi-pass mode. Printing in such cases is performed at full print head resolution but the amount of data to be printed is distributed between the successive print scans. Such multi pass printing method contributes to print quality and provides a better redundancy, since different nozzles participate in printing sections of the same line.

[0006] In order to print an image in multi pass printing the substrate is usually advanced on a multiple of print resolution. The multiple of the print resolution may be smaller or larger than one. This relatively small incremental movement continues until the whole image is printed and requires high position accuracy, which is generally hard or even impossible to achieve by the movement of the large and flexible substrate. Errors in butting such two successive print head scans result in micro

banding effects called printing artifacts. In single pass printing each successive movement of the print head in the second printing direction prints a swath of color equal in width to the print head width. Errors in butting two successive print head wide or print structure wide swaths result in macro banding, which is also called printing artifact. In both cases the butting of two successive image swaths should be perfect, since human eye is extremely sensitive to printing artifacts caused by errors in relative positioning of the print head and substrate. (For the simplicity of explanation the term "print head" will be used for both single print head and a plurality or print heads organized on a common mechanical structure.)

[0007] There are known in the art constructions of ink jet printing machines that have a drum or a table on which the substrate is placed for printing. The accuracy of the relative movement between a rigid drum or table holding the substrate and the print head that moves on linear guides is relatively good and creates small image artifacts. These printers have however, a very large footprint, are expensive and difficult to maintain. A significant number of wide format printing applications, however is done on flexible substrate. Special printing machines termed Roll-to-Roll (R2R) printing machines, are typically used for printing on such substrates. Because the substrate has no support structures these machines have small footprint and high-speed operation. The R2R machines print on five-meter wide flexible substrates. One of the drawbacks of the Roll-to-Roll printing machines is the low accuracy of the relative movement between such a wide flexible substrate and the print head.

[0008] Figure 1 illustrates a typical Roll-to-Roll (R2R) printing machine. The machine has a substrate supply roll **100**, a substrate-collecting roll **102**, and a print head **106**. Rotation of substrate collecting roll **102** pulls substrate **108** of substrate supply roll **100** and moves it in a first printing direction indicated by arrow **110**. Print head **106** reciprocally moves in a second printing direction indicated by arrow **112**. The second printing direction is generally orthogonal to the first printing direction. Mechanism enabling print head **106** reciprocating movement in the second direction indicated by arrow **112** may be a linear motor with a guide **116**, or a metal band or linear guides with a screw drive. A regular motor (not shown) or a motor with a gear may drive substrate-collecting roll **102**. Control computer **114** controls operation of print head **106** and the printer.

[0009] Perfect swath butting, especially in multi pass printing is difficult to achieve on R2R printers. When pooled/moved flexible substrate easy stretches and deforms and accordingly changes its dimensions. This makes small, comparable with the printing resolution incremental movement of flexible substrate with accuracy of few microns nearly impossible.

[0010] Printing of large size images on wide flexible substrates requires not only global dimensions accuracy; it requires multiple local position corrections that compensate for errors in the image printed. Errors caused by wide flexible substrate distortion. These corrections cannot be properly made by the use of encoders. Because of substrate flexibility neither linear nor rotary encoders do not represent accurately the substrate position. There are however, no known methods of other than encoder signal derived information for local image correction.

[0011] The inventors of the present invention are also not aware of any known methods of local image correction that account for actual image on substrate position.

SUMMARY OF THE INVENTION

[0012] There is therefore a need in the industry to provide a method of printing on wide format flexible substrates free of the described above problems.

[0013] There is an additional need to improve the quality of the printed image by accurately butting successive swaths and swath filling scans of printed image in multi pass printing mode.

[0014] There is a further need in the industry to provide a low cost method of image printing capable of providing accurate local printed image position correction and reducing printing artifacts. A low cost method of image printing that accounts for actual image or substrate position.

[0015] Generally, these objectives may be achieved by a method of multi pass inkjet printing on wide format flexible substrates where printing image artifacts cased by

errors (deformations) in flexible substrate positions are corrected by adapting the geometry and position of the next printed swath to the geometry and position of the adjacent earlier printed image swath.

[0016] Exemplary embodiments of the present invention are directed to a method and apparatus that compensates for errors in the image position caused by deformations of wide format flexible substrate movement by printing with a smaller amount of nozzles than supported by the print head and using the non-operative nozzles for substrate position error correction. This is achieved by splitting virtually the print head on inner section of nozzles and peripheral section of nozzles and controlling an ink jet print head drop ejection nozzle position as function of the actual printed image on substrate position. The control of the drop ejecting nozzle position is achieved by shifting data to be printed between the inner and peripheral nozzles of the print head. The shift of data between inner and peripheral nozzles takes place during the multi pass printing process. Proper activation and positioning of the drop ejecting nozzle compensates for errors in the image on substrate position caused by wide format substrate movement deformations and reduces or eliminates micro and macro-banding effects causing printed image artifacts.

[0017] According to one exemplary embodiment the objectives of the present invention are achieved by replacing the small incremental wide format flexible substrate movement in the first direction by shift of the data to be printed between the inner and peripheral nozzles of the print head. The shift of data between inner and peripheral nozzles of the print head provides an image position shift in the first direction. Filling the printed swath by reciprocating scanning movement of the print head in second direction and moving the substrate in the first printing direction in swath wide steps. The magnitude of the data shift between the two sections of nozzles is equivalent to small incremental movement or stepping of the substrate in the first direction and is a function of nozzle pitch (**P**) distance and printing resolution (**R**).

[0018] In accordance with this embodiment the objectives of the present invention may be achieved by a method of inkjet printing on wide format flexible substrates, comprising steps of: providing an inkjet printer having a print head, a substrate, and a control computer; moving the substrate in the first printing direction and scanning the

substrate by reciprocally moving the print head in the second printing direction, orthogonal to the first printing direction, the print head having further its nozzles split virtually on inner section of nozzles and peripheral section of nozzles and having capability of shifting the data to be printed (back and forth) between the inner and peripheral nozzle sections; the data shift being equivalent to the image shift in the first printing direction; printing an image on the substrate by swaths generally narrower than print head width (W); filling the printed swath by reciprocating scanning movement of the print head in the second direction and shifting the data to be printed between the inner nozzle sections and peripheral nozzle sections on a multiple of print resolution (R) in the first scanning direction (back and forth); moving the substrate in swath wide steps in first printing direction and where the control computer distributes the movement in the first direction between the substrate and the shift of data provided to the print head.

[0019] According to another exemplary embodiment the objectives of the present invention may be achieved by advancing the wide format flexible substrate on a small incremental step and printing simultaneously with the image certain image position control marks. Image position control marks may be printed (located) on image free areas of the substrate. Alternatively image position control marks may be printed (located) within the image or on the image area. Image position control marks may be printed by visible or invisible to human eye ink. Coordinates of the image position control marks printed simultaneously with the image define the actual position of the printed image on the substrate and the substrate itself.

[0020] Image position detectors detect image position control marks coordinates and communicate these coordinates to the control computer. The substrate typically moves in first printing direction only. Print head, which generally moves in second printing direction, has its nozzles virtually split on inner section of nozzles and peripheral section of nozzles and has further capability of shifting the data to be printed (back and forth) between the inner and peripheral nozzle sections. The substrate movement error compensation is performed by shifting the data to be printed (back and forth) between the inner and peripheral nozzle sections of print head in the first printing direction simultaneously with the movement of the print head in the second direction. Control computer calculates the error compensation value by

comparing the actual image position with the desired or target image position. Control computer generates appropriate correction signal that causes a shift of the data to be printed (back and forth) between the inner and peripheral nozzle sections of the print head.

[0021] In accordance with this embodiment the objectives of the present invention may be achieved by a method of inkjet printing on wide format flexible substrates, comprising steps of: providing an inkjet printer having a print head, a substrate, image position detecting means, and a control computer; moving the substrate in the first printing direction and scanning the substrate by reciprocally moving the print head in the second printing direction, orthogonal to the first printing direction, the print head has its nozzles virtually split on inner section of nozzles and peripheral section of nozzles and has further capability of shifting the data to be printed (back and forth) between the inner and peripheral nozzle sections in the first printing direction; printing simultaneously with the image a series of image position control marks, which define actual image on the substrate position; detecting by substrate position detecting means the control marks coordinates and providing the control marks coordinates to the control computer; calculating the image position deviation value from the desired image position and wherein the ink jet printing is performed by correcting the image position error by shifting the data to be printed between the inner section of nozzles and peripheral nozzle section; the shift of data being equivalent to image movement in the first direction in accordance with the image position deviation value calculated by the control computer.

[0022] The substrate position error is corrected by shifting data to be printed between the inner section of nozzles and peripheral section of nozzles in the first printing direction on a step matching the error (deviation) in image position. The shift of the data to be printed between the inner section of nozzles and peripheral section of nozzles may be performed concurrently and continuously with the printed swath-filling scan.

[0023] The method of wide format inkjet printing on flexible substrate that derives the printing position based on the printed image position or on the position of digitally

introduced image position control elements. Specially introduced printed marks may serve as image on substrate position control marks or elements.

[0024] Image position control marks may be printed (located) on image free areas of the substrate. Alternatively image position control marks may be printed on the areas of the substrate occupied by the image. Image position control marks may be printed by invisible or visible to the human eye ink.

[0025] According to a further exemplary embodiment the objectives of the present invention may be achieved by continuously monitoring the advance of the wide format flexible substrate and correcting image position by shifting the data to be printed (back and forth) between the inner and peripheral nozzle sections of the print head. The substrate movement error compensation is performed by shifting the data to be printed (back and forth) between the inner and peripheral nozzle sections of print head in the first printing direction simultaneously with the movement of the print head in the second direction. Control computer calculates the error compensation value by comparing the actual substrate position with the desired or target substrate position. Control computer generates appropriate correction signal that causes associated with it shift of the data to be printed (back and forth) between the inner and peripheral nozzle sections of the print head.

[0026] Continuous monitoring of the substrate advance and position may be performed by non-contact or contact substrate advance and position monitoring means. Non-contact means may be optical mouse type sensors or other similar sensors. Contact means may be simple metering rolls that are in contact with the substrate.

[0027] According to one exemplary embodiment the printing method of the present invention is enabled by an inkjet printing apparatus for printing on wide format flexible substrates, comprising: a substrate and a mechanism for moving the substrate, a print head having its nozzles split on an inner section nozzles and peripheral section nozzles and being capable of shifting the data to be printed between the inner section nozzles and peripheral section nozzles of the print head, image position detecting means, and a control computer; the substrate moving mechanism moves the substrate

in the first printing direction and the print head moving mechanism scans the substrate by reciprocally moving the print head in the second printing direction, orthogonal to the first printing direction; the print head has further its nozzles virtually split on an inner section nozzles and peripheral section nozzles and being capable of shifting the data to be printed between the inner section nozzles and peripheral section nozzles of the print head (back and forth); the print head prints simultaneously an image and a series of image position control marks, coordinates of the image position control marks provide information on actual image position; the image position detecting means, detect the image position control marks coordinates and communicate the coordinates to the control computer; the control computer calculates the deviation of the actual image position from the desired (target) image position, and whereby the inkjet printing is performed by correcting the image position error along the second printing direction by shifting the data to be printed between the inner section nozzles and peripheral section nozzles of the print head in the first printing direction in accordance with the image position deviation value .

[0028] An inkjet printing apparatus for printing on wide format flexible substrates where image position control marks may be printed by ink invisible or visible to human eyes.

[0029] The shift of data to be printed between the inner section nozzles and peripheral section nozzles of the print head is equivalent to image shift in the first printing direction on a value matching the image position deviation value compensates for the substrate position error.

[0030] An inkjet printing apparatus for printing on wide format flexible substrates where image position detection means are one of a group of photodiode, quadrant detector, solar element, CCD, or video camera.

[0031] An inkjet printing apparatus for printing on wide format flexible substrates where a control computer processes the image position deviation value describing the deviation of the actual printed image swath position from the desired (target) image swath position and generates a signal for shifting the data between the inner section of nozzles and the peripheral section of nozzles of the print head.

[0032] According to another exemplary embodiment the printing method of the present invention is enabled by an inkjet printing apparatus for printing on wide format flexible substrates, comprising: a substrate and a mechanism for moving the substrate, a print head having its nozzles split on an inner section nozzles and peripheral section nozzles and being capable of shifting the data to be printed between the inner section nozzles and peripheral section nozzles of the print head, substrate position detecting means, and a control computer; the substrate moving mechanism moves the substrate in the first printing direction and the print head moving mechanism scans the substrate by reciprocally moving the print head in the second printing direction, orthogonal to the first printing direction; the print head further has its nozzles virtually split on an inner section nozzles and peripheral section nozzles and being capable of shifting the data to be printed between the inner section nozzles and peripheral section nozzles of the print head it in the first printing direction (back and forth); substrate position detecting means continuously monitor substrate position, and communicate the position to the control computer; the control computer calculates the deviation of the actual substrate position from the desired (target) substrate position, and whereby the inkjet printing is performed by correcting the substrate position error along the second printing direction by shifting the data to be printed between the inner section nozzles and peripheral section nozzles of the print head in the first printing direction in accordance with the image position deviation value .

[0033] The shift of data to be printed between the inner section nozzles and peripheral section nozzles of the print head is equivalent to image shift in the first printing direction on a value matching the substrate position deviation value compensates for the substrate position error.

[0034] An inkjet printing apparatus for printing on wide format flexible substrates where non-contact substrate position detection means are optical mouse type sensors or other similar sensors.

[0035] An inkjet printing apparatus for printing on wide format flexible substrates where substrate position detection means are contact means such as metering rolls that are in contact with the substrate.

[0036] An inkjet printing apparatus for printing on wide format flexible substrates where a control computer processes the image position deviation value describing the deviation of the actual substrate position from the desired (target) substrate position and generates a signal for shifting the data between the inner section of nozzles and the peripheral section of nozzles of the print head.

[0037] The advantage of the method is that it reduces the swaths macro and micro banding effects and adapts the geometry of the image to the actual position of the previous swath reducing the undesired visual effects (printing artifacts) caused by deformations in substrate size during substrate movement.

[0038] A further advantage of the method is that it does not make use of auxiliary substrate supports such as drum, table, endless metal bands or precisely formed surface reducing by this the manufacturing cost of the printing apparatus.

[0039] It is an additional advantage of the method disclosed that the printing position information is derived from the previously printed image position or actual substrate position without the use of costly auxiliary position monitoring devices.

BRIEF DESCRIPTION OF THE DRAWINGS

[0040] The foregoing and other objects, features and advantages of the invention will be apparent from the more particular description of the exemplary embodiments of the invention, as illustrated in the accompanying drawings in which like reference numbers refer to the same parts throughout the different figures. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

[0041] Figure 1 is a schematic representation of a simplified prior art roll-to-roll inkjet printer;

[0042] Figures 2A and 2B are schematic illustration of an inkjet printer and a swath of an image printed by prior art multi pass printing method;

[0043] Figures 3 is schematic illustration of additional prior art multi pass image printing methods;

[0044] Figures 4A and 4B are schematic illustrations of an inkjet printer and an image printed by a multi pass printing method in accordance with one of the exemplary embodiments of the present invention;

[0045] Figures 5A and 5B are schematic illustrations of an inkjet printer and an image printed by a multi pass printing method in accordance with another exemplary embodiment of the present invention;

[0046] Figure 6 is a simplified flow chart of image on substrate position control marks placement decision making algorithm;

[0047] Figures 7A and 7B are schematic illustrations of an inkjet printer constructed in accordance with an additional exemplary embodiment of the present invention;

[0048] Figure 8 is a detailed schematic illustrations of contact substrate position monitoring means constructed in accordance with the present invention;

DETAILED DESCRIPTION OF THE INVENTION

[0049] The principles and execution of a method according to the present invention, and the operation and properties of an ink jet printing apparatus enabling the printing method may be understood with reference to the drawings and the accompanying description of non-limiting, exemplary embodiments.

[0050] Reference is now made to Figures 2A and 2B which are schematic illustrations of a prior art printer and a prior art multi pass printing method. Print head **120** is printing an image consisting of a number of swaths and in particular print swath of the image bounded by lines of rectangle **122**. Print head nozzle pitch **P** is lower than the

required print resolution **R** and in order to fill print swath bounded by lines of rectangle **122** the printing is performed in a multi pass mode. For the simplicity of explanation the printing resolution **R** is equal in both first and second directions. Substrate **108** is advanced in the first direction indicated by arrow **110.** When print head **120** scans in the second direction indicated by arrow **124** each of print head **120** nozzles **126** prints respective line shown as separate square pixels **130a**. Numeral **122'** (Fig. 2B) marks new swath boundaries. At the end of the scan substrate **108** is incrementally advanced in the first direction (first printing direction) indicated by arrow **110**, print head **120** moves back (reciprocating type of movement) in the direction indicated by arrow **146** (Fig. 2B) and each of the nozzles **126** prints respective print line shown as separate square pixels **130b**. The process continues until the swath bounded by lines of rectangle **122** is filled in. (The previous scan is shown in lines and characters having lower density.)

[0051] As illustrated in Fig. 2B the incremental advance of substrate **108** having large dimensions and being flexible is not equal along print head scan path. When pulled or moved by other means, wide size flexible substrate **108** stretches or skews and undergoes other types of distortions. These stretches and skews create visually disturbing micro banding effects (printing artifacts) shown in Figure 2B. (The printed image should have homogeneous structure and be free form visible micro and macro banding effects or artifacts.) Other numerals on Figures 2A and 2B indicate: **136** and **138** are motors that provide movement to substrate-collecting roll **102**, and print head **120** respectively; **140** is a linear guide on which print head **120** travels (scans) forth and back; **122'** designates lines of rectangle that bounds print swath printed by print head **120** when it moves back (reciprocating type of movement) in the direction indicated by arrow **146**.

[0052] Figures 2A and 2B illustrate a certain type of printed swath filling pattern in a multi pass printing mode. Some additional prior art technique for printed swath filling patterns in a multi pass printing mode is illustrated in Figure 3. Figure 3 shows a possible multi pass printing method with a print head **132** having nozzles **134** pitch **P** equal to the printing resolution **R**. Two passes are required to fill-in printed swath bounded by lines **150**. The data to be printed may be equally distributed between the passes. Such multi pass printing method contributes to print quality and provides a

higher redundancy level, since different nozzles participate in printing the same line when scanning the substrate in a reciprocating type of movement. The swath width and swath-filling rate were introduced for exemplary purposes only and other ratios are possible.

[0053] Present invention discloses a method and an apparatus for ink jet printing on wide format flexible substrates that reduces visually disturbing micro banding errors caused by deformations, stretches and skews of the wide format flexible substrate. Figure 4A is an illustration of an inkjet printer constructed in accordance with one of the embodiments of the present invention and a swath of a printed image printed by the printer of the present invention. Ink ejecting nozzles distributed along print head **174** width (W) are split virtually into inner section nozzles (**IN**) and peripheral section nozzles (**PER**). Not like in the existing prior art inkjet printers for the purpose of filling in printed swath **176** shift of the data from inner section nozzles (**IN**) to peripheral section nozzles (**PER**) of print head **174** replaces the small incremental advance of flexible substrate **108**. Shift of the data between inner nozzles (**IN**) to peripheral nozzles (**PER**) of print head **174** is equivalent to printed image shift in the first direction indicated by arrow **170**. Direction **170** is generally parallel with first direction indicated by arrow **110**. (Figure 4 shows direction **170** of shift of the data between inner nozzles to peripheral nozzles of print head as a vertical one. It is necessary to mention that the method is applicable to any print head position and to any shift direction.)

[0054] Print head moving mechanism moves print head **174** in the direction indicated by arrow **124** from one edge of substrate **108** to the second edge of substrate **108**. In course of this movement nozzles **184** of print head **174** eject ink droplets and print a swath bounded by lines of rectangle **176.** Each nozzle **184** preferably of the inner nozzles section of print head **174** prints a line of pixels **178a**. The printing is performed in multi pass mode. In accordance with the present invention for the purpose of filling in printed swath **176** shift of the data between inner section nozzles to peripheral section nozzles of print head **174** in the first direction replaces the small incremental advance of flexible substrate **108**. Figure 4B shows printing of the next swath-filling scan. When print head makes the next scan moving in the direction of arrow **146** it prints pixels **178b**. For printing pixel(s) **178b** the data was shifted from

the inner section nozzles (**IN**) to the lower peripheral section nozzles (**PER**) of print head **174**. Numeral **210** introduced for illustrative purposes only, marks the shift. Substrate **108** remains stationary during the swath filling process. The multi pass swath-filling pattern has been shown for exemplary purposes only. Other swath filling patterns are possible. (Due to imperfections of the drawing software some artifacts may be present on the drawing.)

[0055] Following completion of swath filling wide flexible substrate **108** advances on swath width (**W**) in the first direction and positions substrate 108 in a position for next swath do be printed. The distribution of the movement in the first direction between the shift of nozzles of print head **174** and wide flexible substrate **108** advance significantly reduces micro banding effects and associated with them printing artifacts. Control computer **114** controls the shift of data between the nozzles of print head **174** and the distribution of the movements in the first direction between the shift (of data) between the nozzles of print head **174** and substrate **108**.

[0056] In accordance with another exemplary embodiment shown in Figure 5A inkjet printing apparatus of the present invention in addition to print head **174** having its nozzles split virtually on inner section nozzles and peripheral section nozzles has image position detecting means **180**. Image position detection means **180** may be located along the second printing direction. Generally, image position detection means **180** should be of extended form to cover the whole width of printing substrate **108**. Alternatively image position detection means **180** may be positioned at predefined locations over substrate **108**. Their position may be fixed or adjustable as appropriate for a particular machine design. Image position detection means **180** include a source of illumination and a detector. The source of illumination may be an incandescent lamp, a LED or a laser diode operating in visible or non-visible range of spectrum. The detector may be a photodiode, a quadrant detector, a CCD, or a video camera type detector. Control computer **114** controls operation of all units of the printer.

[0057] For printing, substrate-moving mechanism moves substrate **108** in first printing direction indicated by arrow **110**. Print head moving mechanism moves print head **174** in the direction indicated by arrow **124** from one edge of substrate **108** to the

second edge of substrate **108**. In course of this movement print head **174** ejects ink droplets and prints a swath bounded by lines of rectangle **190**. The printing is performed in multi pass mode. In accordance with the present invention concurrently to printing a print swath of an image print head **120** prints in predefined positions image position control marks **200**.

[0058] Control marks **200** may be printed on image free areas of the substrate or on areas of the substrate occupied by an image. When control marks 200 are printed on image free areas or on the edges of the substrate the shift between the inner and peripheral nozzle sections is some how less accurate, since the correction shift of the data is calculated based on the coordinates of two, located at the edges of the image, points only. Control marks **200** may be printed by ink visible to human eye or invisible to human eye.

[0059] Following each successive swath print, wide flexible substrate **108** advances on the required small distance in the first direction. This advance of wide flexible substrate **108** is not an accurate one, since deformations introduced into wide flexible substrate are not homogeneous across the width of substrate. In order to compensate for deficiencies of substrate moving mechanism, resulting in micro banding, image on substrate position detecting means **180** detect and measure the coordinates of image position control marks **200**.

[0060] Substrate position detecting means **180** communicate the coordinates of image position control marks **200** to control computer **114**. Image position control marks **200** are indicators of the actual image position (and the position of substrate itself). Control computer **114** uses the coordinates of image position control marks **200** to calculate the deviation of the actual image or pixel position from the target or desired image position. Control computer **114** calculates the required correction data shift between the inner and peripheral nozzles of print head **174** with respect to the previously printed swath.

[0061] In accordance with the present invention in course of print head **174** movement in the second direction indicated by arrow **146** (Fig. 5B) continuous corrective data shift between inner and peripheral sections of nozzles takes place. The

shift creates printed image movement, which is generally parallel to first printing direction **110**. The continuous corrective data shift compensates for deformations and an error caused by wide format flexible substrate movement and reduces visible micro banding effects. Figure 5B shows that when print head makes the next scan moving in the direction of arrow **146** and printing pixels **192b** the data shift has involved in printing one peripheral nozzle (**PER**) at the beginning of the scan and on two peripheral nozzles at the end of the scan. Allover data shift was two nozzles and the printed image position was shift accordingly.

[0062] In practice the method of multi pass inkjet printing on wide format flexible substrates adapts the geometry and position of the next printed swath to the geometry and position of the adjacent earlier printed image swath.

[0063] As illustrated in figures 2B and 5B wide flexible substrates do not deform in a homogeneous way along their width or length and some areas of the printed image may have deformations larger than the other. In order to correct the micro and macro printed swath butting errors caused by the non-homogeneous deformation of wide format flexible substrate along the printed swath image position control marks should be located along and across a printed swath enabling dynamic print head position correction. Image position control marks **200** may have any shape suitable for machine detection and convenient for deriving based on the image on substrate position detector readings the actual new position of flexible substrate **108**. The size of image on substrate position control marks **200** is selected to enable reliable position detection without affecting image quality or content.

[0064] Figure 5B illustrates an exemplary placement and form of image position control marks **200** along and across printed swath **190** and **190'**. When position control marks **200** are located along and across printed swath i.e., within the printed image itself their size and color should be selected in way that does not created undesired visual effects. Alternatively image position control marks **200** may be printed by invisible to human eye ink.

[0065] Digital image analysis precedes or is made concurrently with the swath printing process. The purpose of the analysis is to define proper position locations of

image position control marks **200** along and across printed swath **190**. Figure 6 shows a simplified image position control marks **200** position locations algorithm. Initially, (step **230**) the digital image to be printed is partitioned into printed swaths and strips of image pertaining to the same swath are defined. Printing is usually performed in four process colors cyan, magenta, yellow and black (CMYK). The proportion of each of the process colors within each of the swaths is different and at step **232** ink coverage or content for a particular printed swath is calculated for each ink. Image position control marks **200** are preferably printed by a color (ink) that has largest coverage (proportion) in a particular swath. This ink is selected at step **234**. Further to this image on substrate position control marks printed when print head moves in the direction indicated by arrow **124** are preferably placed in places that will be overprinted by ink of the same color when print head **120** will move in the direction indicated by arrow **146**. In order to find suitable control marks places within the image at step **238** swath with highest ink content is further analyzed for sections having clusters of inked pixels of sufficient size for marks placement.

[0066] Distribution of image on substrate position control marks along and across printed swath in a way that enables relatively smooth continuous corrective data shift between the nozzles of print head **174** definition of which takes place at step **240**. The processed swath is printed simultaneously with image position control marks at step **242**. The process continues in a similar way for the next swath.

[0067] Distribution of image positions control marks along and across printed swath in a way that enables relatively smooth continuous corrective data shift between the nozzles of print head **174** within a single color (ink) may not always be possible. Highlight print areas may have not enough dense clusters for proper control marks positioning. In such extreme cases image on substrate position control marks may be placed in more than one printing color (ink).

[0068] Alternatively image position control marks may be printed by ink invisible to human eye, but easy detectable by image position detection means. Such marks may be printed in any location on the substrate and no special image processing is required. Printing control marks by ink invisible to human eyes requires however, an additional print head and increases the cost of the machine.

[0069] Image position control marks provide an effective tool for image position control. Monitoring the substrate position and shifting the data accordingly may achieve similar results. Figure 7A is a schematic illustrations of an inkjet printer constructed in accordance with an additional exemplary embodiment of the present invention. Printer of figure 7A is similar in structure to the printer of figure 5, except that image position sensors **180** have been replaced by non-contact substrate poison detection means **250**. Non-contact substrate position detection means **250** may be optical mouse type sensors such as ADNS – 2051 commercially available from Agilent Technologies, Inc. Palo Alto, CA 94303 U.S.A., or other similar sensors. Substrate position detection means **250** detect distortions, schematically shown by phantom line **254**, caused by wide format flexible substrates movement. Substrate position detection means **250** are in communication with control computer **114** that receives substrate distortion coordinates and shifts accordingly the data to be printed between the inner nozzles section and peripheral nozzles section. The continuous corrective data shift compensates for deformations and errors caused by wide format flexible substrate movement and reduces visible micro banding effects.

[0070] Wide format flexible substrate deformations, as shown in figure 7B by phantom lines **254** and **264,** are non-homogeneous along the printed swath. There may be instances in which the edges of substrate **108** are deformed, but central section of substrate **108** marked by phantom line **260** is not deformed. A second set of substrate position detection means **250'** disposed in a position allowing monitoring of the lower part of printed swath providing a more accurate correction value and accordingly the shift of data between inner and peripheral sections of nozzles of print head **174**. A variety of signal processing methods that are per-se not part of the invention may be used to process the position signals provided by substrate position detectors **250** and **250'**.

[0071] In an alternative embodiment non-contact substrate position detection means **250** may be replaced by contact substrate position detection means such as metering rollers that are in permanent contact with substrate **108**. Figure 8 shows such a metering roller **280** contacting substrate **108**. In order to avoid any roller slippage the contact surface of roller **280** has an abrasive type coating **284**. Roller **280** typically

has certain preload and it is desirable, but not necessary to have some type of back support surface **288** that facilitates the metering process.

[0072] Although the exemplary embodiments illustrate so-called micro banding artifacts correction, or correction of artifacts between the successive scans within the same print swath, the method is applicable to corrections of the macro banding artifacts or artifacts between two relatively wide printed swaths.

[0073] Prints printed by the disclosed printer produce images of significantly improved quality, as compared to existing printers. They do not exhibit micro banding effects and have reduced macro-banding effects. The width of printed substrate may be further increased without damaging print quality.

[0074] The above disclosure is intended as merely exemplary, and not to limit the scope of the invention, which is to be determined by reference to the appended claims.

What is claimed is:

1. A method of multi pass inkjet printing on wide format flexible substrates, comprising steps of:

   a. providing an inkjet printer having a print head, a substrate, and a control computer;

      i) said print head further having ink ejecting nozzles distributed along said width (W) and split virtually into inner section nozzles and peripheral sections nozzles;

   b. moving said substrate in first printing direction and scanning said substrate by reciprocally moving said print head in second printing direction, orthogonal to said first printing direction;

c. printing an image on said substrate by print head wide (W) swaths and filing said printed swath by reciprocating scanning movement of said print head in second direction;

wherein said multi pass inkjet printing is performed by shifting drop ejection nozzles position from inner section nozzles to peripheral nozzles said shift in drop ejection nozzles position in first direction compensates for deformations caused by wide format flexible substrate movement in said first printing direction.

2. A method of ink jet printing on wide format flexible substrates, as in claim 1 wherein said control computer controls the step of selective shift of ink ejecting nozzles position in said first direction.

3. A method of inkjet printing on wide format flexible substrates, comprising steps of:

a. providing an inkjet printer having a print head, a substrate, image on substrate position detection means, and a control computer;

i) said print head further having ink ejecting nozzles distributed along said width (W) and split virtually into inner section nozzles and peripheral sections nozzles;

b. moving said substrate in first printing direction and scanning said substrate by reciprocally moving said print head in second printing direction, orthogonal to said first printing direction;

c. printing simultaneously with an image a series of image position control marks, said control marks defining actual image position of said substrate;

d. detecting by said substrate position detecting means said control marks coordinates and providing said control marks coordinates to said control computer;

e. calculating the deviation value of said actual wide format flexible substrate position from the desired (target) substrate position, and

wherein said inkjet printing is performed by correcting said wide format flexible substrate position error by shifting ink ejecting nozzles position along print head width generally parallel to said first printing direction in accordance with said deviation value.

4. A method of ink jet printing on wide format flexible substrates, as in claim 3 wherein the step of image position control marks positions said marks outside the image area.

5. A method of ink jet printing on wide format flexible substrates, as in claim 3 wherein the step of image position control marks positions said marks within the image area.

6. A method of ink jet printing on wide format flexible substrates, as in claim 3 wherein the step of image position control marks positions said marks in places that will be overprinted by ink of the same color.

7. A method of ink jet printing on wide format flexible substrates, as in claim 3 wherein the step of printing image position control marks is performed with ink visible to human eyes.

8. A method of ink jet printing on wide format flexible substrates, as in claim 3 wherein the step of image position control marks printing is performed with ink invisible to human eyes.

9. A method of ink jet printing on wide format flexible substrates, as in claim 3 wherein the step of defining the direction of selective shift of ink ejecting nozzles position along print head width generally parallel to said first direction is derived from actual printed swath on substrate position.

10. An ink jet printing apparatus for printing on wide format flexible substrates, comprising:

a. a substrate and a mechanism for moving said substrate, a print head and a mechanism for moving said print head, substrate position detecting means, and a control computer;

ii) said print head further having ink ejecting nozzles distributed along said width (W) split virtually into inner section nozzles and peripheral sections nozzles;

b. said substrate moving mechanism moves said substrate in first printing direction and said print head moving mechanism scans said substrate by reciprocally moving said print head in second printing direction, orthogonal to said first printing direction;

c. said print head prints simultaneously an image and a series of image on substrate position control marks, coordinates of said marks provide information on actual position of said image on substrate;

d. said image on substrate position detecting means, detect said image on substrate position control marks coordinates defining actual image on substrate position and communicate said coordinates to said control computer;

e. said control computer calculates the deviation of said actual image on substrate position from the theoretical (target) image on substrate position, and

whereby said inkjet printing is performed by shifting ink ejecting nozzles position along print head width generally parallel to said first printing direction in accordance with said deviation value.

11. An ink jet printing apparatus for printing on wide format flexible substrates, as in claim 10 and where substrate detection means are one of a group of photodiode, position detector, video camera.

12. A method of multi pass inkjet printing on wide format flexible substrates where errors in flexible substrate positions are corrected by selective shift of ink ejecting nozzles position on said deviation value and where said selective shift of ink ejecting nozzles position is performed in the same direction as said wide format flexible substrate moves.

13. A method of multi pass inkjet printing on wide format flexible substrates where errors in flexible substrate positions are corrected by adapting the geometry and position of the next printed swath to the geometry of the adjacent earlier printed image swath.

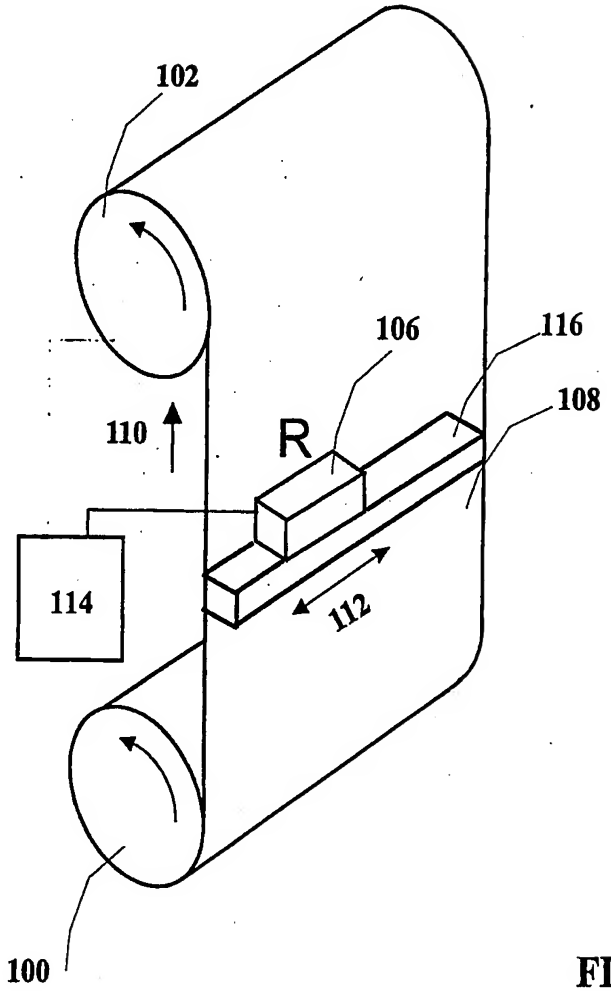


FIG. 1

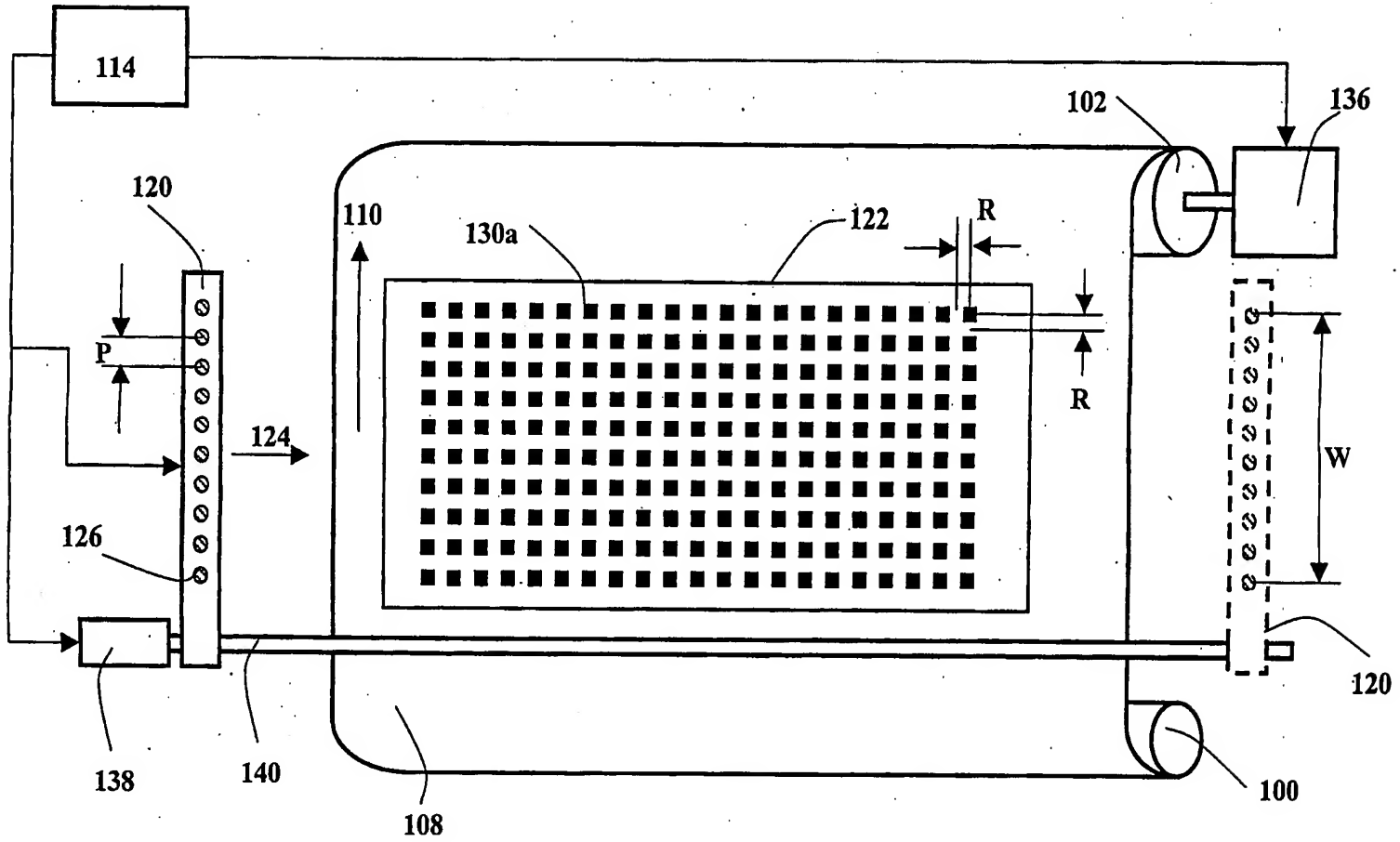


FIG. 2A. PRIOR ART

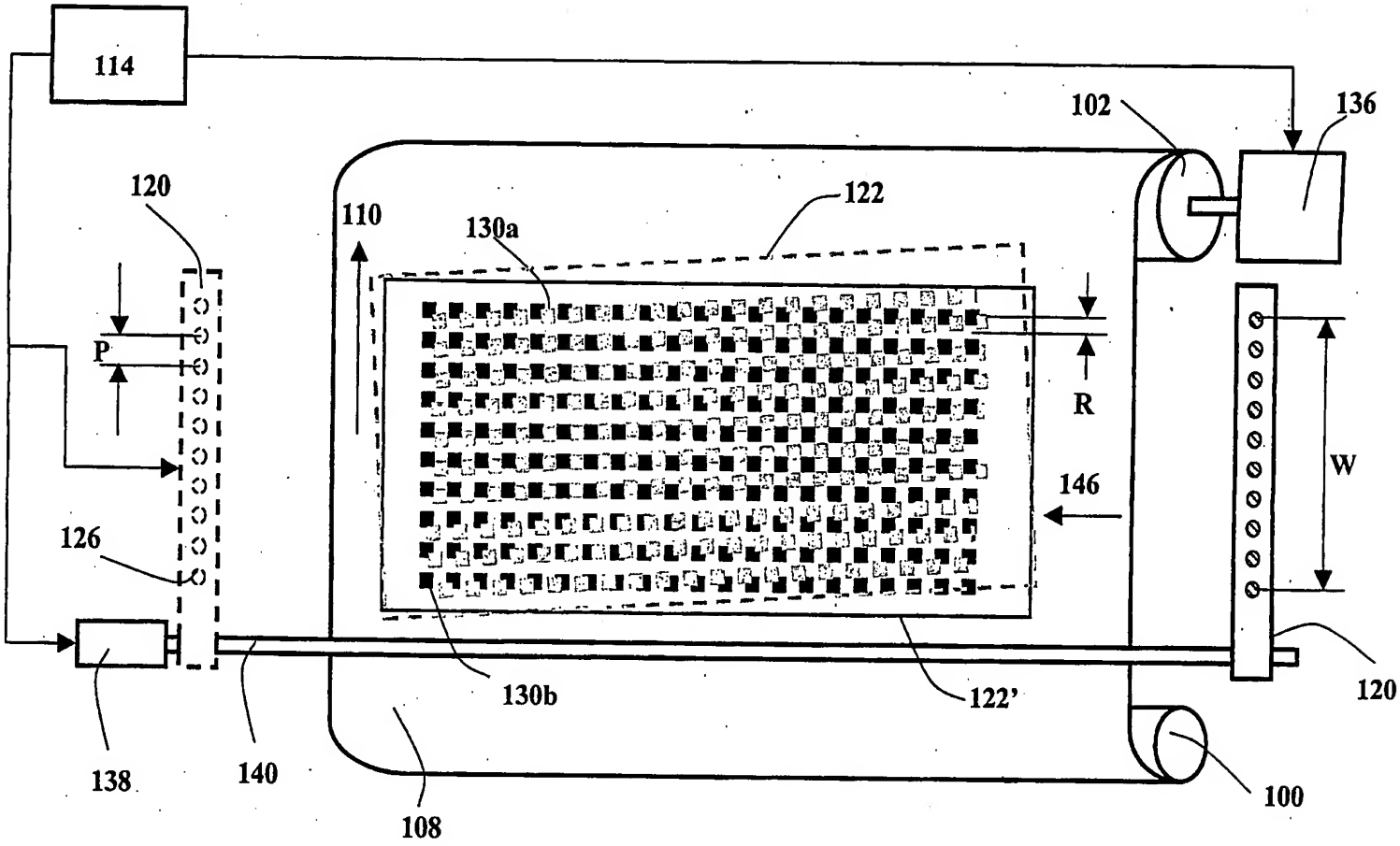


FIG. 2B. PRIOR ART

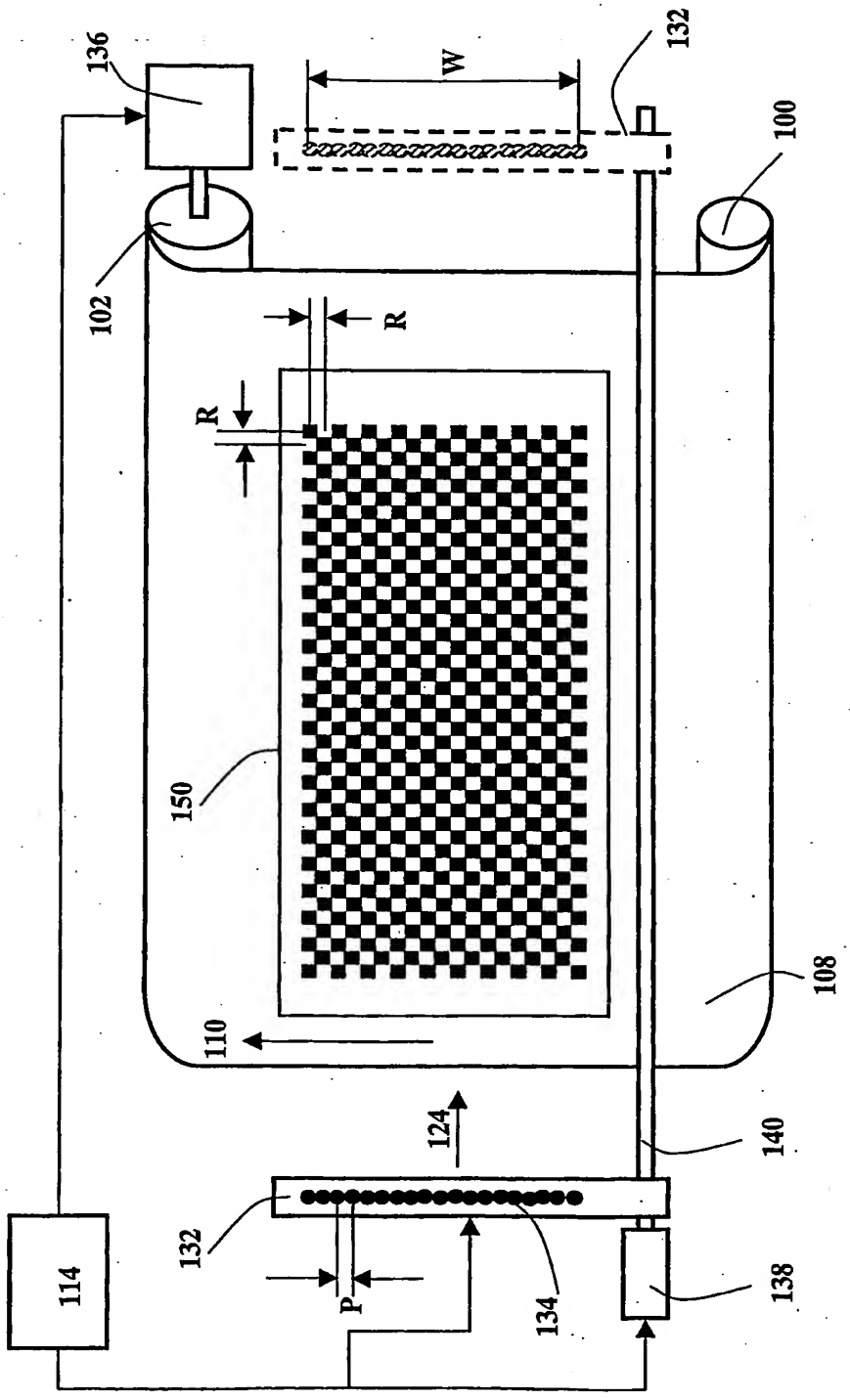


FIG. 3.

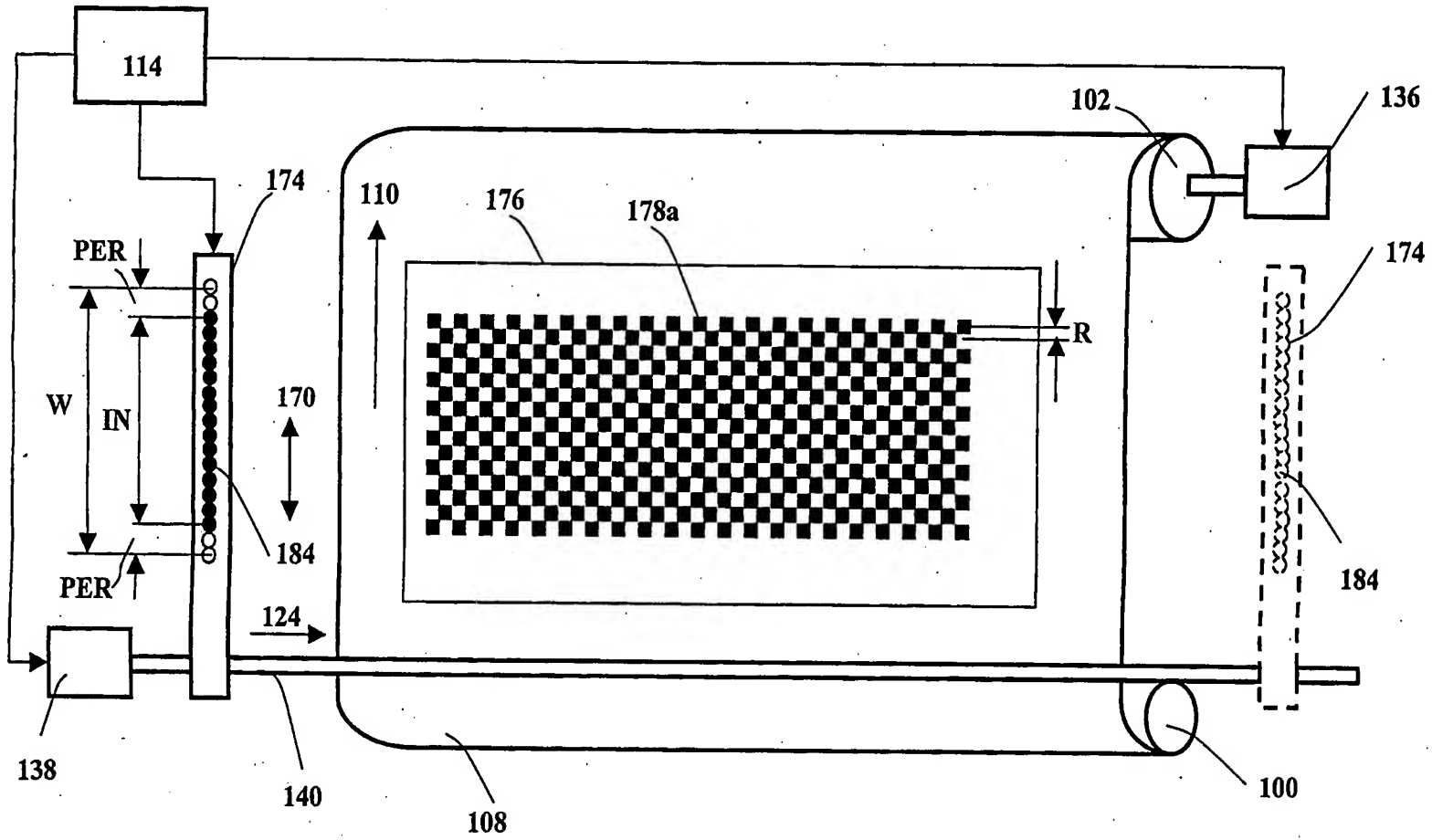

114
102
136
174
110
176
178a
174
PER
R
W
IN
170
184
PER
184
124
138
140
108
100

FIG. 4A

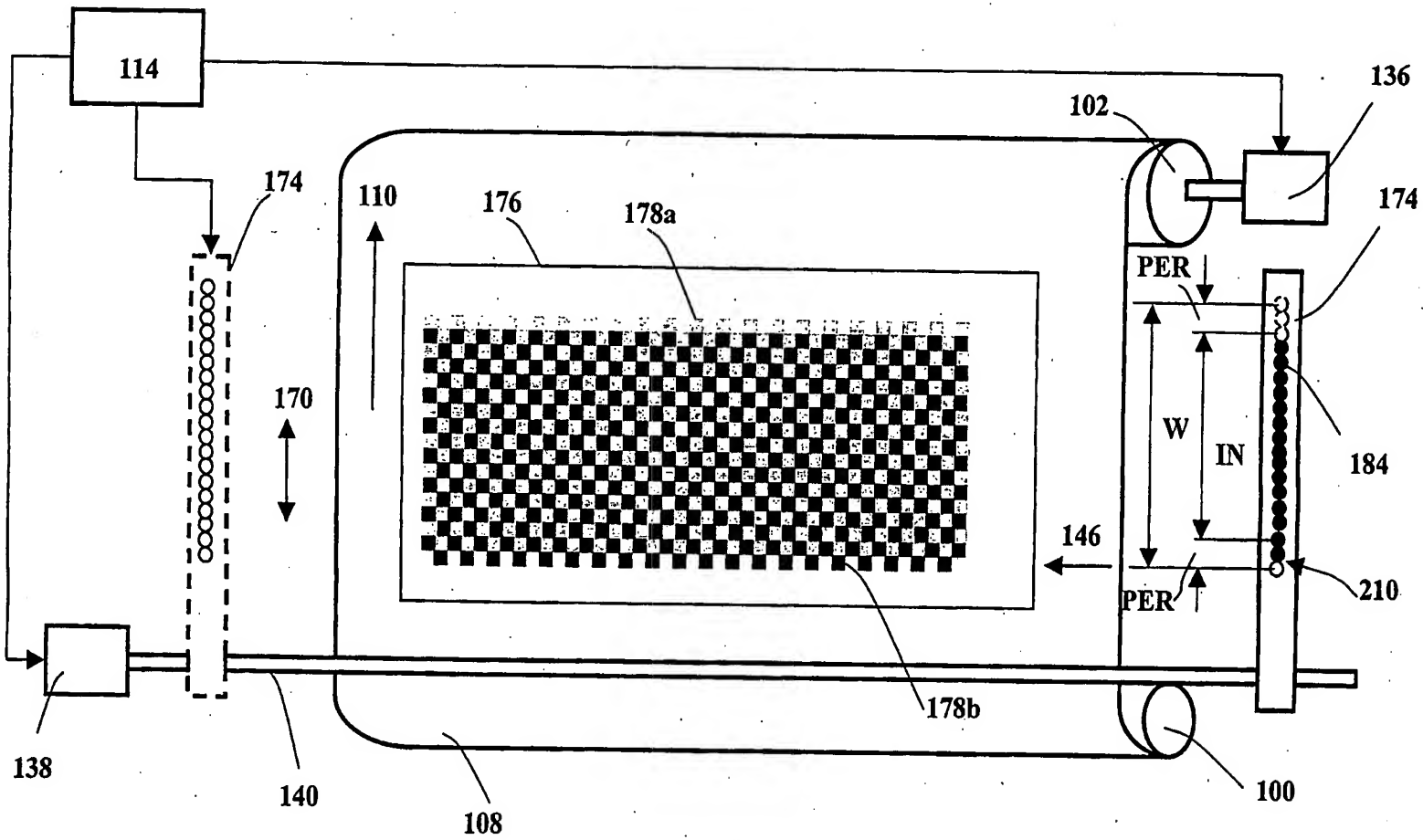
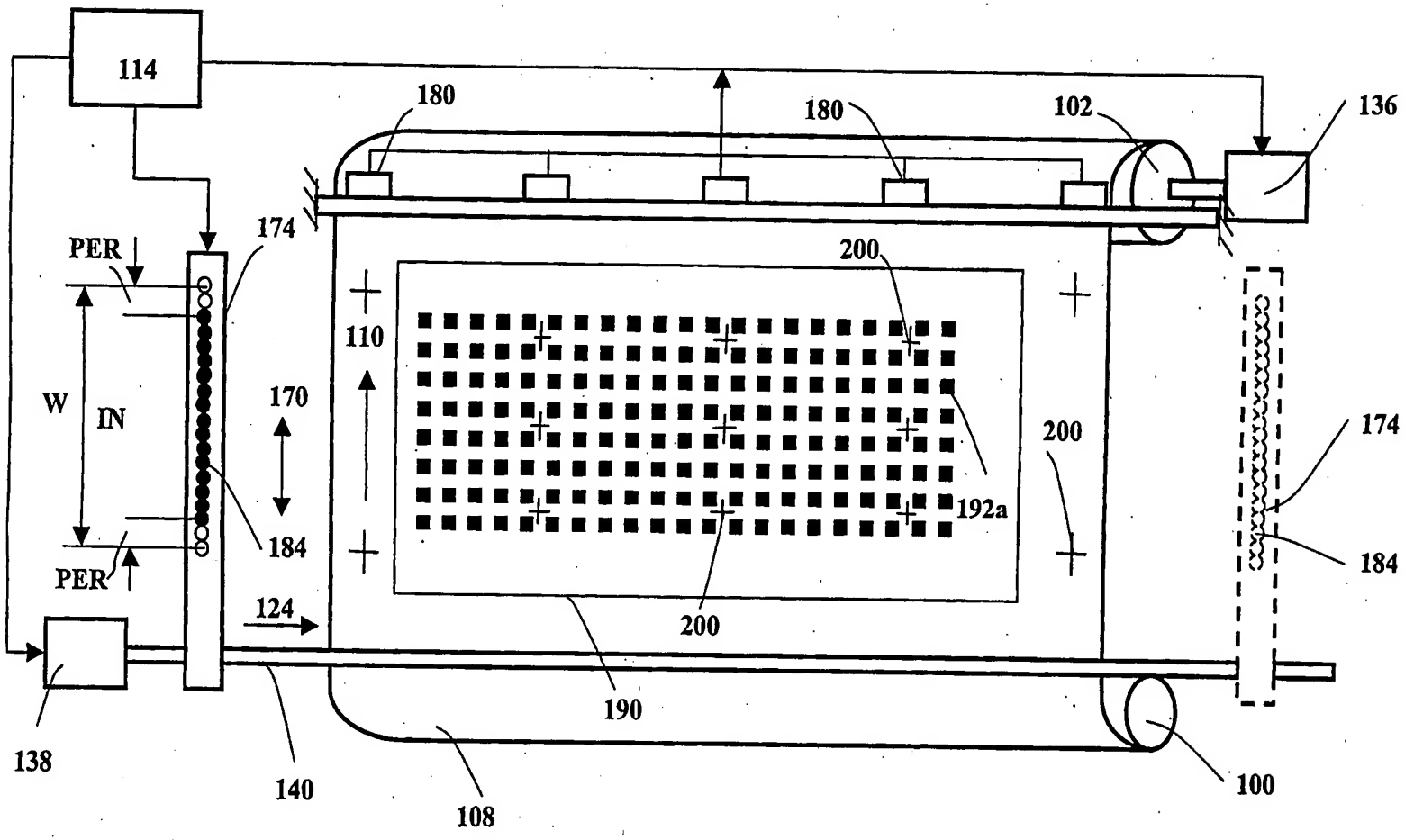

114
136
102
174
110
176
178a
174
PER
170
W
IN
184
146
PER
210
178b
138
140
108
100

FIG. 4B


114
180
180
102
136
174
PER
200
110
W
IN
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192a
184
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184
124
200
190
138
140
108
100

FIG. 5A

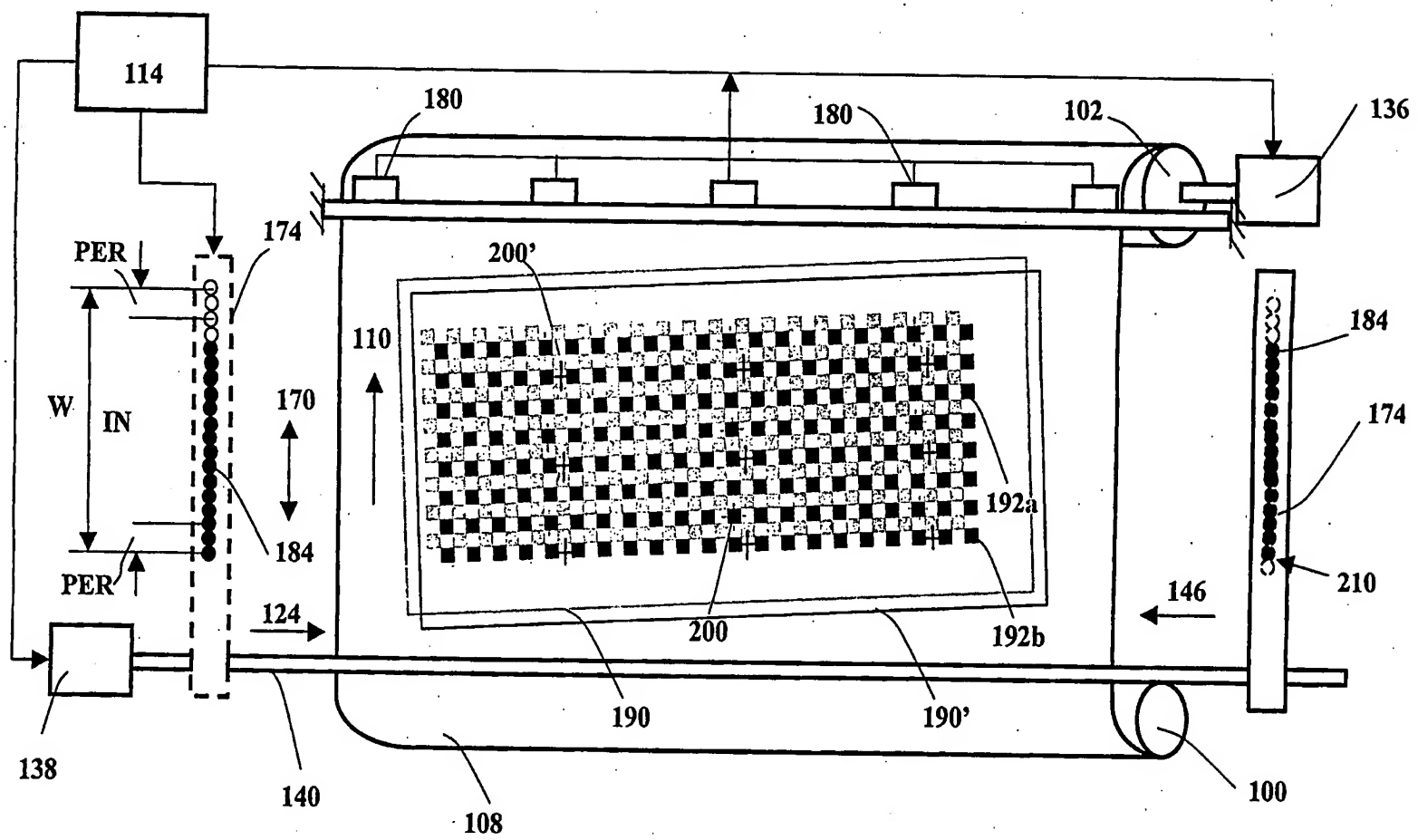
114
180
180
102
136
174
PER
200'
110
184
W
IN
170
192a
PER
184
124
146
210
200
192b
190
190'
138
140
108
100

FIG. 5B

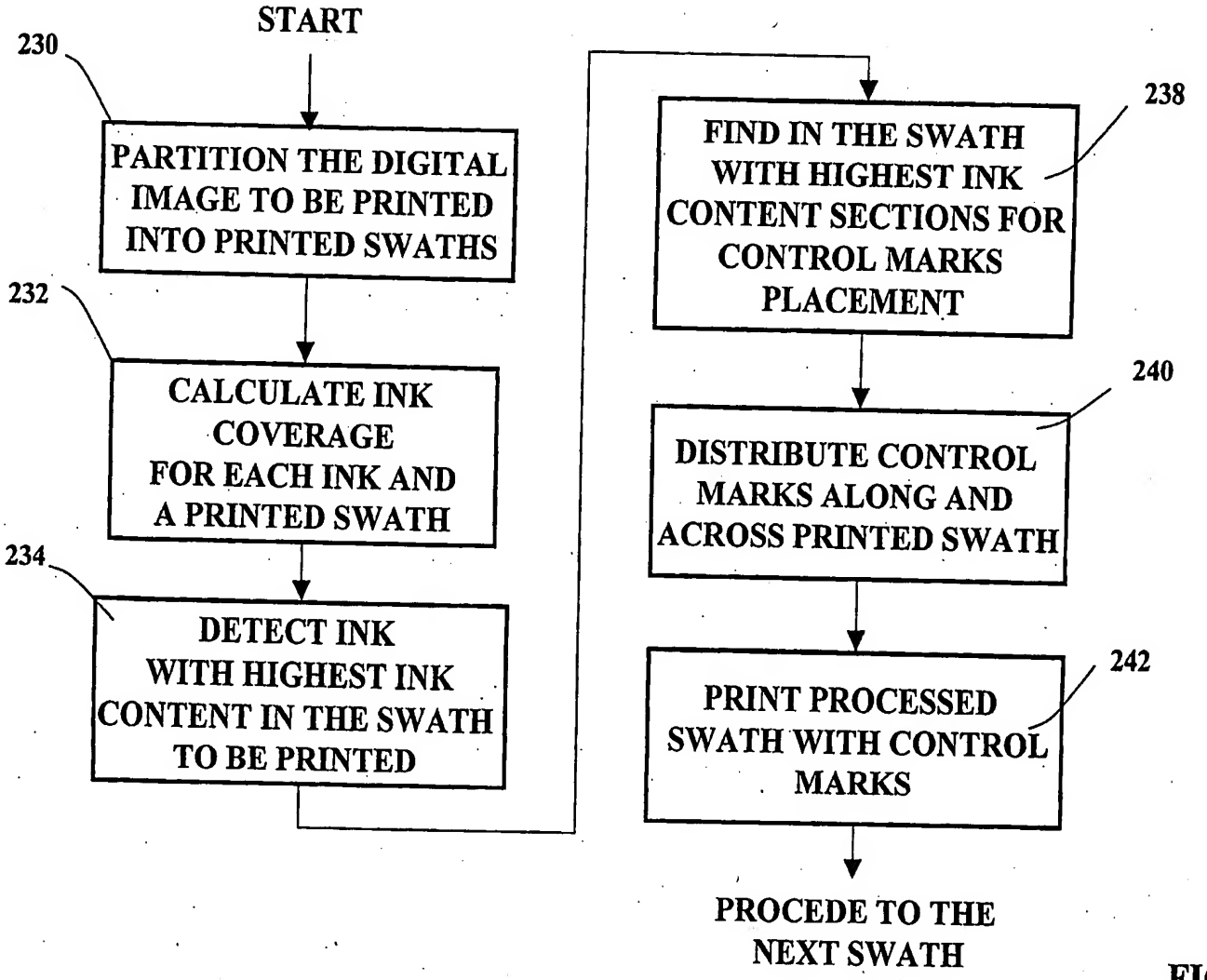
START
230
PARTITION THE DIGITAL IMAGE TO BE PRINTED INTO PRINTED SWATHS
232
CALCULATE INK COVERAGE FOR EACH INK AND A PRINTED SWATH
234
DETECT INK WITH HIGHEST INK CONTENT IN THE SWATH TO BE PRINTED
238
FIND IN THE SWATH WITH HIGHEST INK CONTENT SECTIONS FOR CONTROL MARKS PLACEMENT
240
DISTRIBUTE CONTROL MARKS ALONG AND ACROSS PRINTED SWATH
242
PRINT PROCESSED SWATH WITH CONTROL MARKS
PROCEDE TO THE NEXT SWATH

FIG. 6.

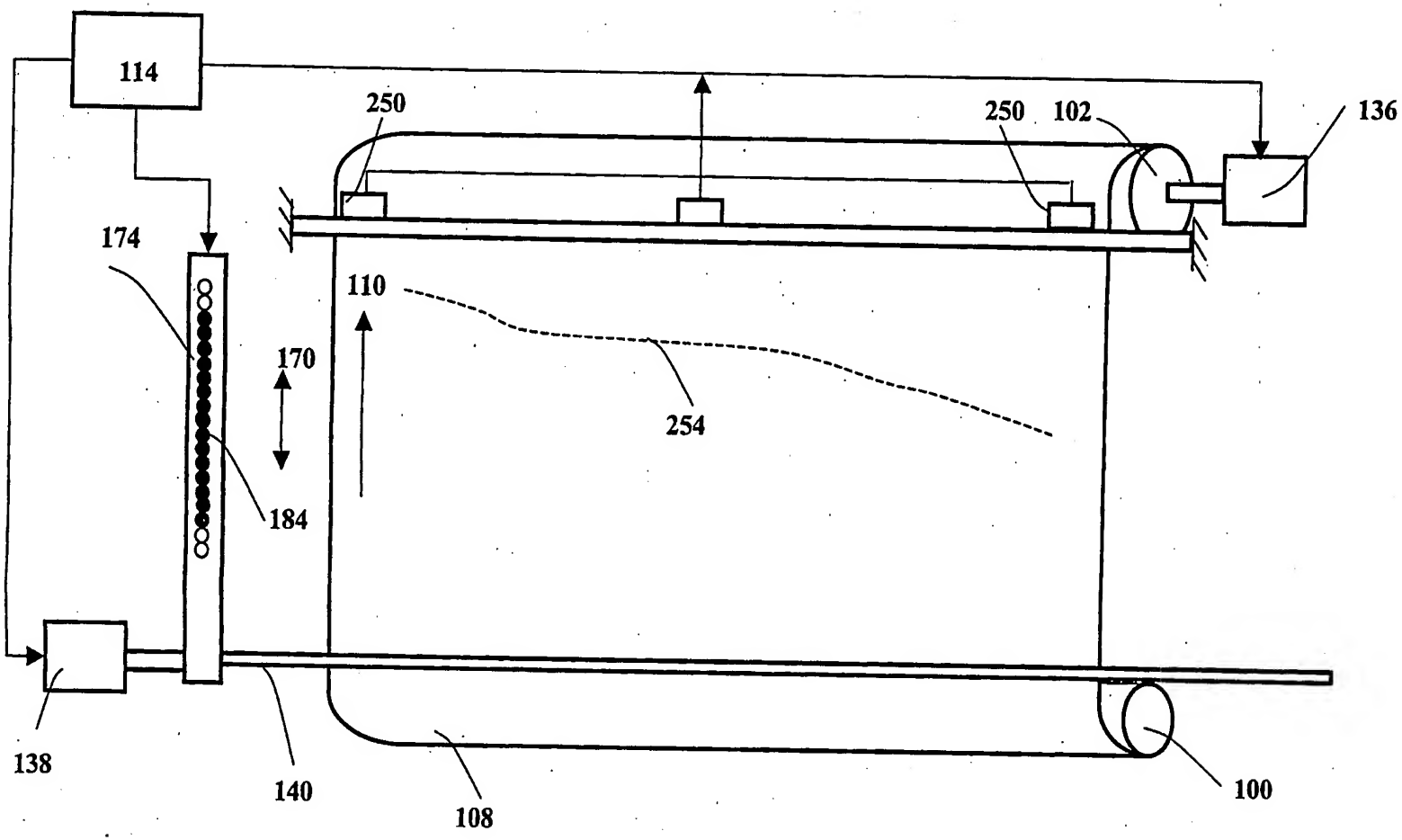

FIG. 7A

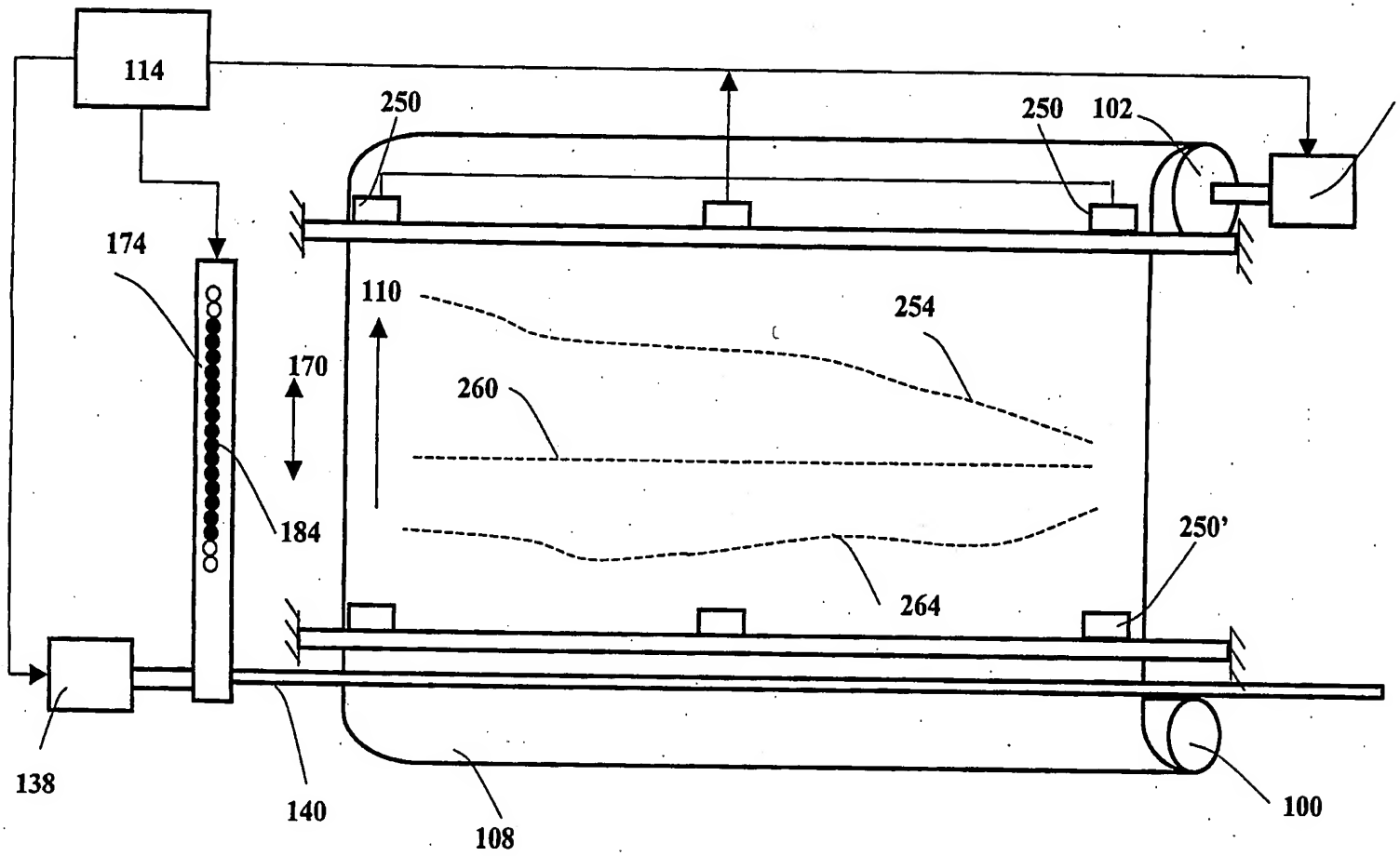
114
250
250
102
136
174
110
254
170
260
184
250'
264
138
140
108
100

FIG. 7B

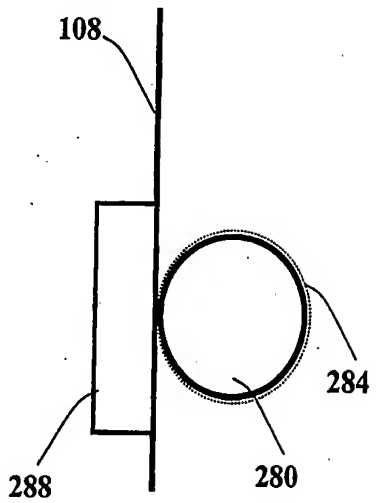

FIG. 8.

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161210
תאריך: Date
הוקדם/נדחה
01-04-2004
Ante/Post- dated

בקשה לפטנט
PATENT APPLICATION

אני, (שם המבקש, מענו - ולגבי גוף מאוגד - מקום התאגדותו)
סאיטקס ויזן בע"מ
רח" הצורן 5ג
ת.ד. 8743
נתניה 42505

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ממציאים: אהרון כורם ויגור יעקובוב.

INVENTORS: AHARON KOREM AND IGOR YAKUBOV

בעל אמצאה מכח העברה ASSIGNMENT ששמה הוא:
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(בעברית שיטת הדפסה על מצא גמיש רחב ומדפסת
(Hebrew)

(באנגלית)
A METHOD OF PRINTING ON LARGE FORMAT FLEXIBLE SUBSTRATE AND PRINTING APPARATUS (English)

hereby apply for a patent to be granted to me in respect thereof. מבקש בזאת כי ינתן לי עליה פטנט.

*בקשת חלוקה- Application for Division	*בקשת פטנט מוסף- Application for Patent of Addition	*דרישת דין קדימה Priority Claim		
מבקשת פטנט from application	לבקשה/לפטנט to Patent/Appl.	מספר/סימן Number/Mark	תאריך Date	מדינת האיגוד Convention Country
No מס'	No מס'			
dated מיום	dated מיום			

*יפוי כח: כללי/מיוחד - רצוף בזה / עוד יוגש
P.O.A.: general / specific - attached / to be filed later-

הוגש בענין Has been filed in case

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ת.ד. 8743
נתניה 42505

היום 17 בחודש מרץ שנת 2004
This day 17 Of March of the year 2004

חתימת המבקש
Signature of Applicant

Rafi Bronstein
Scitex Vision Ltd.
IP Manager

REFERENCE: סימוכין:

טופס זה, כשהוא מוטבע בחותם לשכת הפטנטים ומושלם במספר ובתאריך ההגשה, הינו אישור להגשת הבקשה שפרטיה רשומים לעיל
This form, impressed with the Seal of the Patent Office and indicating the number and date of filing, certifies the filing of the application, the particulars of which are set out above.

*מחק את המיותר Delete whatever is inapplicable

ABSTARCT OF THE INVENTION

The present invention discloses a method of multi pass inkjet printing on wide format flexible substrates where errors in flexible substrate positions are corrected by adapting the geometry and position of the next printed swath to the geometry of the adjacent earlier printed image swath.

APPLICATION FOR PATENT

Title: A METHOD OF PRINTING ON LARGE FORMAT FLEXIBLE SUBSTRATE AND PRINTING APPARATUS

FIELD OF THE INVENTION

[0001] The present invention relates to the field of inkjet printing and particularly to printing on large format flexible substrates.

BACKGROUND OF THE INVENTION

[0002] Inkjet printing has gained popularity in a number of applications. One of the growing printing applications is printing of billboards, banners and point of sale displays. The ink-jet printing process involves manipulation of drops of ink ejected from an orifice or a number of orifices of a print head onto an adjacent print substrate. Paper, vinyl, textiles, fabrics, and others are examples of print substrates. An ink-jet print head consists of an array or a matrix of ink nozzles, with each nozzle selectively ejecting ink droplets. A given nozzle of the print head ejects the droplet in a predefined print position on the substrate. An assembly of the adjacently positioned on the substrate ink droplets creates a predetermined print pattern or image. Relative movement between the substrate and the print head enables substrate coverage and image creation. Each ink droplet comprises a picture element, or "pixel." Good print quality requires printing resolution higher that 600 pixel per inch. A typical pitch of an array of nozzles is however 180 or less nozzles per inch.

[0003] To produce the relative movement enabling image creation the substrate moves in one direction termed first direction, and print head moves in another direction termed second direction. The second direction is usually orthogonal to the first direction. Generally, the print head has less weight and is much smaller in size than substrate. It is convenient to move print head fast over the substrate in a type of reciprocating movement. Each successive reciprocating scan by such a print head in the second direction creates a relatively wide ink-marked strip or printed swath. The substrate is advancing simultaneously in the second direction.

[0004] In order to cover the substrate with the desired print resolution of for example 720 pixel per inch a single print head with nozzle pitch of 180 nozzles per inch has to scan in a reciprocating type of movement the print swath four times. Each scan is distant from the previous one on 1/720 of inch. The data to be printed is divided accordingly between the scans. This type of printing is called multi pass printing mode. Alternatively for printing at 720 pixels per inch resolution four print heads with nozzle pitch of 180 nozzles per inch may be organized on a common mechanical structure shifted one with respect to the other on a 1/720 of an inch. Organized in this manner print heads may print the desired image in a single pass printing mode, providing better ink coverage and creating more vivid colors. The cost of such print head structure is however too high for regular commercial use. Common structures with print heads shifted one with respect to the other on a fraction of a print head dimension (staggered) are also known in the art.

[0005] Recently inkjet print heads such as XAAR Leopard having nozzle pitch of 300 nozzles per inch and commercially available from XAAR Plc., Cambridge, UK and MAGIC having nozzle pitch of 600 nozzles per inch and commercially available from Scitex Vision Ltd., Netanya, Israel have appeared on the market. Although these print heads have nozzle pitch suitable for high quality printing the printing itself is performed in multi-pass mode. Printing in such cases is performed at full print head resolution but the amount of data to be printed is distributed between the successive print scans. Such multi pass printing method contributes to print quality and provides a better redundancy, since different nozzles participate in printing sections of the same line when scanning the substrate in a reciprocating type of movement.

[0006] In order to print an image in multi pass printing the substrate is usually advanced on a multiple of print resolution. The multiple may have a value smaller and larger than one. This relatively small incremental movement continues until the whole image is printed and requires high position accuracy, which is generally hard or even impossible to achieve by the movement of the large and flexible substrate. Errors in butting such two successive print head scan result in micro banding effects called printing artifacts. In single pass printing each successive movement of the print head in the second printing direction prints a swath of color equal in width to the print head

width. Errors in butting two successive print head wide or print structure wide swaths result in macro banding, which is also called printing artifact. In both cases the butting of two successive image swaths should be perfect, since human eye is extremely sensitive to printing artifacts caused by errors in relative positioning of the print head and substrate. (For the simplicity of explanation the term "print head" will be used for both single print head and a plurality or print heads organized on a common mechanical structure.)

[0007] There are known in the art constructions of ink jet printing machines that have a drum or a table on which the substrate is placed for printing. The accuracy of the relative movement between a rigid drum or table holding the substrate and the print head that moves on linear guides is relatively good and creates small image artifacts. These printers have however, a very large footprint, are expensive and difficult to maintain. A significant number of wide format printing applications, however is done on flexible substrate. Special printing machines termed Roll-to-Roll (R2R) printing machines, are typically used for printing on such substrates. Because the substrate has no support structures these machines have small footprint and high-speed operation. The R2R machines print on five-meter wide flexible substrates. One of the drawbacks of the Roll-to-Roll printing machines is the low accuracy of the relative movement between such a wide flexible substrate and the print head.

[0008] Figure 1 illustrates a typical Roll-to-Roll (R2R) printing machine. The machine has a substrate supply roll **100**, a substrate-collecting roll **102**, and a print head **106**. Rotation of substrate collecting roll **102** pulls substrate **108** of substrate supply roll **100** and moves it in a first printing direction indicated by arrow **110**. Print head **106** reciprocally moves in a second printing direction indicated by arrow **112**. The second printing direction is generally orthogonal to the first printing direction. Mechanism enabling print head **106** reciprocating movement in the second direction indicated by arrow **112** may be a linear motor with a guide **116**, or a metal band or linear guides with a screw drive. A regular motor (not shown) or a motor with a gear may drive substrate-collecting roll **102**. Control computer **114** controls operation of print head **106** and the printer.

[0009] Perfect swath butting, especially in multi pass printing is difficult to achieve on R2R printers. When pooled/moved flexible substrate easy stretches and deforms

and accordingly changes its dimensions. This makes small, comparable with the printing resolution incremental movement of flexible substrate with accuracy of few microns nearly impossible.

[0010] Printing of large size images on wide flexible substrates requires not only global dimensions accuracy; it requires multiple local position corrections that compensate for errors in the image printed. Errors caused by wide flexible substrate distortion. These corrections cannot be properly made by the use of the encoders. Because of substrate flexibility neither linear nor rotary encoders do not represent accurately the substrate position. There are however, no known methods of other than encoder signal derived information for local image correction.

[0011] The inventors of the present invention are also not aware of any known methods of local image correction that account for actual image on substrate position.

SUMMARY OF THE INVENTION

[0012] There is therefore a need in the industry to provide a method of printing on wide format flexible substrates free of the described above problems.

[0013] There is an additional need to improve the quality of the printed image by accurately butting successive swaths and swath filling scans of printed image in multi pass printing mode.

[0014] There is a further need in the industry to provide a low cost method of image printing capable of providing accurate local printed image position correction and reducing printing artifacts. A low cost method of image printing that accounts for actual image on substrate position.

[0015] Generally, these objectives may be achieved by a method of multi pass inkjet printing on wide format flexible substrates where printing image artifacts cased by errors (deformations) in flexible substrate positions are corrected by adapting the geometry and position of the next printed swath to the geometry of the adjacent earlier printed image swath.

[0016] Exemplary embodiments of the present invention are directed to a method and apparatus that compensates for errors in the image position caused by deformations of wide format flexible substrate movement by moving print head on the deformation (error) value and where the print head movement is performed in the same direction as the wide format flexible substrate moves. The ink jet print head movement is controlled as function of the actual printed image on substrate position. Control of the print head movement takes place during a multi pass printing process. Proper movement and positioning of the print head compensates for errors in the image position caused by wide format flexible substrate deformations and reduces or eliminates micro and macro banding effects causing printed image artifacts.

[0017] According to one exemplary embodiment the objectives of the present invention are achieved by replacing the small incremental wide format flexible substrate movement in the first direction by movement of the print head in the first direction; filling the printed swath by reciprocating scanning movement of the print head in second direction and moving the substrate in the first printing direction in swath wide steps. The magnitude of the small incremental movement or stepping of the print head in the first direction is a function of nozzle pitch (P) distance and printing resolution (R).

[0018] In accordance with this embodiment the objectives of the present invention may be achieved by a method of inkjet printing on wide format flexible substrates, comprising steps of: providing an inkjet printer having a print head, a substrate, and a control computer; moving the substrate in the first printing direction and scanning the substrate by reciprocally moving the print head in the second printing direction, orthogonal to the first printing direction, the print head further having capability of movement in the first printing direction; printing an image on the substrate by print head wide (W) swaths; filling the printed swath by reciprocating scanning movement of the print head in the second direction and stepping the print head on a desired value, which may be a multiple of print resolution (R) in the first scanning direction; moving the substrate in swath wide steps in first printing direction and where the control computer divides the movement in the first direction between said substrate

and said print head movements. (In the context of the present invention the desired value is the step value required to fill in the printed swath.)

[0019] According to another exemplary embodiment the objectives of the present invention may be achieved by advancing the wide format flexible substrate on a small incremental step and printing simultaneously with the image certain image position control marks. Image position control marks may be printed (located) on image free areas of the substrate. Alternatively image position control marks may be printed (located) within the image or on the image area. Image position control marks may be printed by visible or invisible to human eye ink. Coordinates of the image position control marks printed simultaneously with the image define the actual position of the printed image on the substrate and the substrate itself.

[0020] Image position detectors detect image position control marks coordinates and communicate these coordinates to the control computer. The substrate typically moves in first printing direction only. Print head, which generally moves in second printing direction, has additional movement capabilities in the first printing direction. The substrate movement error compensation is performed by selectively and dynamically moving the print head in the first printing direction simultaneously with the movement of the print head in the second direction. Control computer calculates the error compensation value by comparing the actual image position with the desired or target image position. Control computer generates appropriate correction signal that causes associated with it print head movement.

[0021] In accordance with this embodiment the objectives of the present invention may be achieved by a method of inkjet printing on wide format flexible substrates, comprising steps of: providing an inkjet printer having a print head, a substrate, image position detecting means, and a control computer; moving the substrate in the first printing direction and scanning the substrate by reciprocally moving the print head in the second printing direction, orthogonal to the first printing direction, the print head further having capability of movement (back and forth) in the first printing direction; printing simultaneously with the image a series of image position control marks, which define actual image on the substrate position; detecting by substrate position detecting means the control marks coordinates and providing the control marks

coordinates to the control computer; calculating the image position deviation value from the desired image position and wherein the ink jet printing is performed by correcting the image position error by moving dynamically the print head in the first direction in accordance with the image position deviation value calculated by the control computer.

[0022] The image (substrate) position error is corrected by moving the print head in the first printing direction on a step matching the error (deviation) in image position. The movement of the print head may be performed concurrently and continuously with the printed swath-filling scan.

[0023] The method of wide format inkjet printing on flexible substrate that derives the printing position based on the printed image position or on the position of digitally introduced image position control elements. Specially introduced printed marks may serve as image on substrate position control marks or elements.

[0024] Image position control marks may be printed (located) on image free areas of the substrate. Alternatively image position control marks may be printed on the areas of the substrate occupied by the image. Image position control marks may be printed by invisible or visible to the human eye ink.

[0025] The printing method of the present invention is enabled by an inkjet printing apparatus for printing on wide format flexible substrates, comprising: a substrate and a mechanism for moving the substrate, a print head and a mechanism for moving the print head, substrate position detecting means, and a control computer; the substrate moving mechanism moves the substrate in the first printing direction and the print head moving mechanism scans the substrate by reciprocally moving the print head in the second printing direction, orthogonal to the first printing direction; the print head further has a mechanism capable of moving it dynamically in the first printing direction (back and forth); the print head prints simultaneously an image and a series of image position control marks, coordinates of the image position control marks provide information on actual image position; the image position detecting means, detect the image position control marks coordinates and communicate the coordinates to the control computer; the control computer calculates the deviation of the actual

substrate position from the desired (target) substrate position, and whereby the inkjet printing is performed by correcting the image (substrate) position error along the second printing direction by moving the print head in the first printing direction in accordance with the image position deviation value .

[0026] An inkjet printing apparatus for printing on wide format flexible substrates where image position control marks may be printed by ink invisible or visible to human eyes.

[0027] The movement of the print head in the first printing direction on a value matching the image position deviation value compensates for the image (substrate) position error. Linear motors, regular screw drives, metal belts and other movement providing mechanisms or means are among means that may be used to move the print head.

[0028] An inkjet printing apparatus for printing on wide format flexible substrates where image position detection means are one of a group of photodiode, quadrant detector, solar element, CCD, or video camera.

[0029] An inkjet printing apparatus for printing on wide format flexible substrates where a control computer processes the image position deviation value describing the deviation of the actual printed image swath position from the desired (target) image swath position and generates a signal for moving the print head to a corrected scanning position along the second direction.

[0030] The advantage of the method is that it reduces the swaths macro and micro banding effects and adapts the geometry of the image to the actual position of the previous swath reducing the undesired visual effects (printing artifacts) caused by deformations in substrate size during substrate movement.

[0031] A further advantage of the method is that it does not make use of auxiliary substrate supports such as drum, table, endless metal bands or precisely formed surface reducing by this the manufacturing cost of the printing apparatus.

[0032] It is an additional advantage of the method disclosed that the printing position information is derived from the previously printed image position without the use of costly auxiliary image position monitoring means.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] The foregoing and other objects, features and advantages of the invention will be apparent from the more particular description of the exemplary embodiments of the invention, as illustrated in the accompanying drawings in which like reference numbers refer to the same parts throughout the different figures. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

[0034] Figure 1 is a schematic representation of a simplified prior art roll-to-roll inkjet printer;

[0035] Figures 2A and 2B are schematic illustration of an inkjet printer and a swath of an image printed by prior art multi pass printing method;

[0036] Figures 3 is schematic illustration of additional prior art multi pass image printing methods;

[0037] Figures 4A, 4B and 4C are schematic illustrations of an inkjet printer and an image printed by a multi pass printing method in accordance with one of the exemplary embodiments of the present invention;

[0038] Figures 5A and 5B are schematic illustrations of an inkjet printer and an image printed by a multi pass printing method in accordance with another exemplary embodiment of the present invention;

[0039] Figure 6 is a simplified flow chart of image on substrate position control marks placement decision making algorithm;

[0040] Figure 7 is an illustration of an additional exemplary embodiment of micro and macro banding (printing artifacts) reduction in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0041] The principles and execution of a method according to the present invention, and the operation and properties of an ink jet printing apparatus enabling the printing method may be understood with reference to the drawings and the accompanying description of non-limiting, exemplary embodiments.

[0042] Reference is now made to Figures 2A and 2B which are schematic illustrations of a prior art printer and a prior art multi pass printing method. Print head **120** is printing an image consisting of a number of swaths and in particular print swath of the image bounded by lines of rectangle **122**. Print head nozzle pitch **P** is lower than the required print resolution **R** and in order to fill print swath bounded by lines of rectangle **122** the printing is performed in a multi pass mode. For the simplicity of explanation the printing resolution **R** is equal in both first and second directions. Substrate **108** is advanced in the first direction indicated by arrow **110.** When print head **120** scans in the second direction indicated by arrow **124** each of print head **120** nozzles **126** prints respective line shown as separate square pixels **130a**. At the end of the scan substrate **108** is incrementally advanced in the first direction (first printing direction) indicated by arrow **110**, print head **120** moves back (reciprocating type of movement) in the direction indicated by arrow **146** (Fig. 2B) and each of the nozzles **126** prints respective print line shown as separate square pixels **130b**. The process continues until the swath bounded by lines of rectangle **122** is filled in. (The previous scan is shown in lines and characters having lower density.)

[0043] As illustrated in Fig. 2B the incremental advance of substrate **108** having large dimensions and being flexible is not equal along print head scan path. When pulled or moved by other means, wide size flexible substrate **108** stretches or skews and undergoes other types of distortions. These stretches and skews create visually disturbing micro banding effects (printing artifacts) shown in Figure 2B. (The printed image should have homogeneous structure and be free form visible banding effects or

artifacts.) Other numerals on Figures 2A and 2B indicate: **136** and **138** are motors that provide movement to substrate-collecting roll **102**, and print head **120** respectively; **140** is a linear guide on which print head **120** travels (scans) back and forth; **122'** designates lines of rectangle that bounds print swath printed by print head **120** when it moves back (reciprocating type of movement) in the direction indicated by arrow **146**.

[0044] Figures 2A and 2B illustrate a certain type of printed swath filling pattern in a multi pass printing mode. Some additional prior art technique for printed swath filling patterns in a multi pass printing mode is illustrated in Figure 3. Figure 3 shows a possible multi pass printing method with a print head **132** having nozzles **134** pitch **P** equal to the printing resolution **R**. Two passes are required to fill-in printed swath bounded by lines **150**. The data to be printed may be equally distributed between the passes. Such multi pass printing method contributes to print quality and provides a higher redundancy level, since different nozzles participate in printing the same line when scanning the substrate in a reciprocating type of movement. The swath width and swath filling rate were introduced for exemplary purposes only and other ratios are possible.

[0045] Present invention discloses a method and an apparatus for ink jet printing on wide format flexible substrates that reduces visually disturbing micro banding errors caused by deformations, stretches and skews of the wide format flexible substrate. Figure 4A is an illustration of an inkjet printer constructed in accordance with one of the embodiments of the present invention and a swath of a printed image printed by the printer of the present invention. Not like in the existing prior art inkjet printers print head **120** of the inkjet printing apparatus of the present invention in addition to the capability of moving in the second direction indicated by arrow **124** has capability of moving in the first direction (back and forth) indicated by arrow **170**. Direction **170** is generally parallel with first direction indicated by arrow **110**. (Figure 4 shows direction **170** of print head movement as a vertical one. It is necessary to mention that the method is applicable to any print head position and movement direction.)

[0046] Mechanism (means) **174** enabling print head **120** movement in the first direction indicated by arrow **170** may be a linear motor, a metal band or a linear guide with a drive screw. The particular shown mechanism **174** is a regular drive screw

with a motor. Print head moving mechanism **174** moves print head **120** in the direction indicated by arrow **124** from one edge of substrate **108** to the second edge of substrate **108**. In course of this movement print head **120** ejects ink droplets and prints a swath bounded by lines of rectangle **176**. Each nozzle **126** of print head **120** prints a line of pixels **178a**. Print head pitch **P** is lower than the required print resolution **R** and in order to fill-in print swath bounded by lines of rectangle **176** the printing is performed in multi pass mode. In accordance with the present invention for the purpose of filling in printed swath **176** movement of print head **120** in the first direction replaces the small incremental advance of flexible substrate **108**. Figure 4B shows printing of the next swath filling scan. When print head makes the next scan moving in the direction of arrow **146** it prints pixels **178b.** For printing pixel(s) **178b** print head position was changed as indicated on scale **210** on two digit. (Scale **210** is introduced for illustrative purposes only.) Print head **120** movement in the direction indicated by arrow **170** is parallel to the movement of image (substrate) **108** in the first (printing) direction **110** and is relatively small, as compared to the magnitude of substrate **108** movement. Accordingly the print head moving mechanism may have relatively small amplitude of movement and use small size and low cost encoders.

[0047] Figure 4C shows next swath filling print head **120** scanning pass. Four passes are required to fill-in the particular printed swath (the last pass is not shown). The information to be printed is distributed between the swaths. The multi pass swath filling pattern has been shown for exemplary purposes only. Other swath filling patterns are possible.

[0048] Following completion of swath filling wide flexible substrate **108** advances on swath width (**W**) in the first direction and print head moving mechanism **174** returns print head **120** to the initial position. Other movement sequences where the print head is returned into the initial position for example, in course of the beginning of the next swath filling process, are possible. The distribution of the movement in the first direction between print head **120** and wide flexible substrate **108** significantly reduces micro banding effects and associated with them printing artifacts. Control computer **114** controls the movement of print head **120** and the split of movements in the first direction between print head **120** and substrate **108**.

[0049] In accordance with another exemplary embodiment shown in Figure 5A inkjet printing apparatus of the present invention in addition to print head **120** moving means **174** has image position detecting means **180**. Image position detection means **180** may be located along the second printing direction. Generally, image position detection means **180** should be of extended form to cover the whole width of printing substrate **108**. Alternatively image position detection means **180** may be positioned at predefined locations over substrate **108**. Their position may be fixed or adjustable as appropriate for a particular machine design. Image position detection means **180** include a source of illumination and a detector. The source of illumination may be an incandescent lamp, a LED or a laser diode operating in visible or non-visible range of spectrum. The detector may be a photodiode, a quadrant detector a CCD, or a video camera type detector. Control computer **114** controls operation of all units of the printer.

[0050] For printing, substrate-moving mechanism moves substrate **108** in first printing direction indicated by arrow **110**. Print head moving mechanism moves print head **120** in the direction indicated by arrow **124** from one edge of substrate **108** to the second edge of substrate **108**. In course of this movement print head **120** ejects ink droplets and prints a swath bounded by lines of rectangle **190**. Print head pitch **P** is lower than the required print resolution **R** and in order to fill print swath bounded by lines of rectangle **194** the printing is performed in multi pass mode. In accordance with the present invention concurrently to printing a print swath of an image print head **120** prints in predefined positions image on substrate position control marks **200**.

[0051] Following each successive swath print, wide flexible substrate **108** advances on the required distance in the first direction. This advance of wide flexible substrate **108** is not an accurate one, since deformations introduced into wide flexible substrate are not homogeneous across the width of substrate. In order to compensate for deficiencies of substrate moving mechanism, resulting in micro banding, image on substrate position detecting means **180** detect and measure the coordinates of image position control marks **200**.

[0052] Substrate position detecting means **180** communicate the coordinates of image position control marks **200** to control computer **114**. Image on substrate position

control marks **200** are indicators of the actual image on substrate position (and the position of substrate itself). Control computer **114** uses the coordinates of image position control marks **200** to calculate the deviation of the actual image or pixel position from the target or desired image position. The desired (target) image position in this particular configuration is a function of print head pitch and printed image resolution. Control computer **114** calculates the required correction movement of print head **120** with respect to the previously printed swath.

[0053] In accordance with the present invention in course of print head **120** movement in the second direction indicated by arrow **146** print head moving mechanism **174** performs continuous (dynamic) corrective movement of print head **120** in the direction indicated by arrow **170**. This movement is generally parallel to first printing direction **110**. The corrective movement of print head **120** compensates for deformations and an error caused by wide format flexible substrate movement and reduces visible micro banding effects. Scale **210** is introduced for illustrative purposes only. It shows that when print head makes the next scan moving in the direction of arrow **146** and printing pixels **192b** its position was adjusted on one digit at the beginning of the scan and on two digits at the end of the scan. Allover print head movement was three digits.

[0054] Generally, the method of multi pass inkjet printing on wide format flexible substrates adapts the geometry and position of the next printed swath to the geometry and position of the adjacent earlier printed image swath.

[0055] As illustrated in figures 2B and 5B wide flexible substrates do not deform in a homogeneous way along their width or length and some areas of the printed image may have deformations larger than the other. In order to correct the micro and macro printed swath butting errors caused by the non-homogeneous deformation of wide format flexible substrate along the printed swath image position control marks should be located along and across a printed swath enabling dynamic print head position correction. Image position control marks **200** may have any shape suitable for machine detection and convenient for deriving based on the image on substrate position detector readings the actual new position of flexible substrate **108**. The size

of image on substrate position control marks **200** is selected to enable reliable position detection without affecting image quality or content.

[0056] Figure 5B illustrates an exemplary placement and form of image position control marks **200** along and across printed swath **190** and **190'**. When position control marks **200** are located along and across printed swath i.e., within the printed image itself their size and color should be selected in way that does not created undesired visual effects. Alternatively image position control marks **200** may be printed by invisible to human eye ink.

[0057] Digital image analysis precedes or is made concurrently with the swath printing process. The purpose of the analysis is to define proper position locations of image position control marks **200** along and across printed swath **190**. Figure 6 shows a simplified image position control marks **200** position locations algorithm. Initially, (step **230**) the digital image to be printed is partitioned into printed swaths and strips of image pertaining to the same swath are defined. Printing is usually performed in four process colors cyan, magenta, yellow and black (CMYK). The proportion of each of the process colors within each of the swaths is different and at step **232** ink coverage or content for a particular printed swath is calculated for each ink. Image position control marks **204** are preferably printed by a color (ink) that has largest coverage (proportion) in a particular swath. This ink is selected at step **234**. Further to this image on substrate position control marks printed when print head moves in the direction indicated by arrow **124** are preferably placed in places that will be overprinted by ink of the same color when print head **120** will move in the direction indicated by arrow **146**. In order to find suitable control marks places within the image at step **238** swath with highest ink content is further analyzed for sections having clusters of inked pixels of sufficient size for marks placement.

[0058] Distribution of image on substrate position control marks along and across printed swath in a way that enables relatively smooth continuous print head position control takes place at step **240**. The processed swath is printed simultaneously with image on substrate position control marks at step **242**. The process continues in a similar way for the next swath.

[0059] Distribution of image positions control marks along and across printed swath in a way that enables relatively smooth continuous print head position control within a single color (ink) may not always be possible. Highlight print areas may have not enough dense clusters for proper control marks positioning. In such extreme cases image on substrate position control marks may be placed in more than one printing color (ink).

[0060] Alternatively image position control marks may be printed by ink invisible to human eye, but easy detectable by image position detection means. Such marks may be printed in any location on the substrate and not special image processing is required. Printing control marks by ink invisible to human eyes requires however, an additional print head and increases the cost of the machine. Such ink may be a clear ink Crystal UGE-0513 commercially available from Sun Chemicals (Sunjet), Fort Lee, NJ U.S.A.

[0061] Figure 7 shows an additional exemplary embodiment that provides another way of improvement of the printing accuracy and banding effects reduction. A line type mark **256** may be printed as the first line on image free area providing a reference for image on substrate position detectors operation. First printed swath is aligned to this line. Location of image on substrate position detectors along the scanning path enables simultaneous reading of a large number of image on substrate control marks coordinates and provides means for making a practically smooth print head correction movement.

[0062] Although the exemplary embodiments illustrate so-called micro banding artifacts correction, or correction of artifacts between the successive scans within the same print swath, the method is applicable to corrections of the macro banding artifacts or artifacts between two relatively wide printed swaths. The method is also applicable to detection and compensation of missing lines and pixels providing a higher degree of redundancy in multi pass printing without using additional print heads or spare nozzles.

[0063] Prints printed by the disclosed printer produce images of significantly improved quality, as compared to existing printers. They do not exhibit micro banding

effects and have reduced macro-banding effects. The width of printed substrate may be further increased without damaging print quality.

[0064] The above disclosure is intended as merely exemplary, and not to limit the scope of the invention, which is to be determined by reference to the appended claims.

What is claimed is:

1. A method of multi pass inkjet printing on wide format flexible substrates, comprising steps of:

   a. providing an inkjet printer having a print head, a substrate, and a control computer;

   b. moving said substrate in first printing direction and scanning said substrate by reciprocally moving said print head in second printing direction, orthogonal to said first printing direction,

      i) said print head further having capability of movement in said first printing direction (back and forth);

   c. printing an image on said substrate by print head wide (W) swaths;

   d. filling said printed swath by reciprocating scanning movement of said print head in second direction and stepping said print head on a desired value in first direction;

   e. moving said substrate in said first printing direction in swath wide steps, and

   wherein said control computer divides the movement in the first direction between said substrate and said print head movements.

2. A method of ink jet printing on wide format flexible substrates, as in claim 1 wherein the step of print head movement in said first direction is derived from the relation between print head width (W), nozzle pitch (P) and print resolution (R).

3. A method of inkjet printing on wide format flexible substrates, comprising steps of:

a. providing an inkjet printer having a print head, a substrate, image position detecting means, and a control computer;

b. moving said substrate in first printing direction and scanning said substrate by reciprocally moving said print head in second printing direction, orthogonal to said first printing direction;

i) said print head further having capability of movement in said first printing direction (back and forth);

c. printing simultaneously with an image a series of image position control marks, said control marks defining actual image position on said substrate;

d. detecting by said image position detecting means said control marks coordinates and providing said control marks coordinates to said control computer;

e. calculating the image position deviation value of said actual image position from the desired (target) image position, and

wherein said inkjet printing is performed by correcting said image position error by moving said print head dynamically in said first printing direction in accordance with said deviation value.

4. A method of ink jet printing on wide format flexible substrates, as in claim 3 wherein the step of image position control marks printing is performed by ink visible to human eyes.

5. A method of ink jet printing on wide format flexible substrates, as in claim 3 wherein the step of image position control marks are printing by ink invisible to human eyes.

6. A method of ink jet printing on wide format flexible substrates, as in claim 3 wherein the step of image position control marks location is selected within the image area.

7. A method of ink jet printing on wide format flexible substrates, as in claim 3 wherein the step of defining the direction of print head movement in said first direction is derived from actual image position.

8. An ink jet printing apparatus for printing on wide format flexible substrates, comprising:

   a. a substrate and a mechanism for moving said substrate, a print head and a mechanism for moving said print head, image position detecting means, and a control computer;

   b. said substrate moving mechanism moves said substrate in first printing direction and said print head moving mechanism scans said substrate by reciprocally moving said print head in second printing direction, orthogonal to said first printing direction;

   c. said print head further has a mechanism capable of moving it dynamically in said first printing direction (back and forth);

   d. said print head prints simultaneously an image and a series of image position control marks, coordinates of said marks provide information on actual image position on said substrate;

e. said image on substrate position detecting means, detect said image on substrate position control marks coordinates defining actual image on substrate position and communicate said coordinates to said control computer;

f. said control computer calculates the deviation of said actual image position from the desired (target) image position, and

whereby said inkjet printing is performed by correcting said substrate position error by moving said print head in said first printing direction in accordance with said image position deviation value.

9. An ink jet printing apparatus for printing on wide format flexible substrates, as in claim 8 and where substrate detection means are one of a group of photodiode, quadrant detector, CCD and video camera.

10. A method of multi pass inkjet printing on wide format flexible substrates where errors in flexible substrate positions are corrected by moving print head on said deviation value (back and forth) and where said print head movement is performed in the same direction as said wide format flexible substrate moves.

11. A method of multi pass inkjet printing on wide format flexible substrates where errors in flexible substrate positions are corrected by adapting the geometry and position of the next printed swath to the geometry of the adjacent earlier printed image swath.

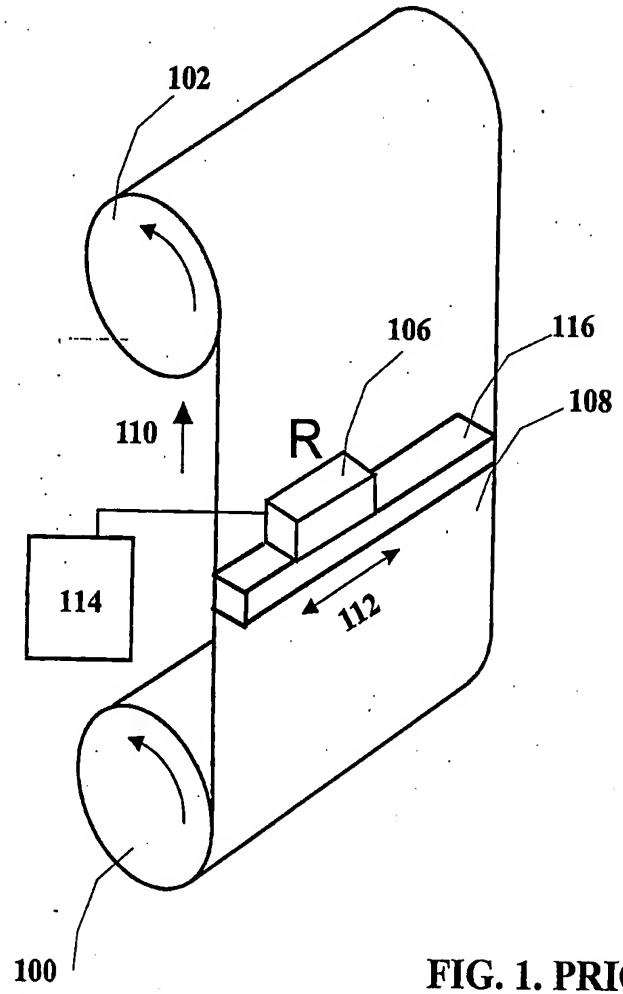


FIG. 1. PRIOR ART.

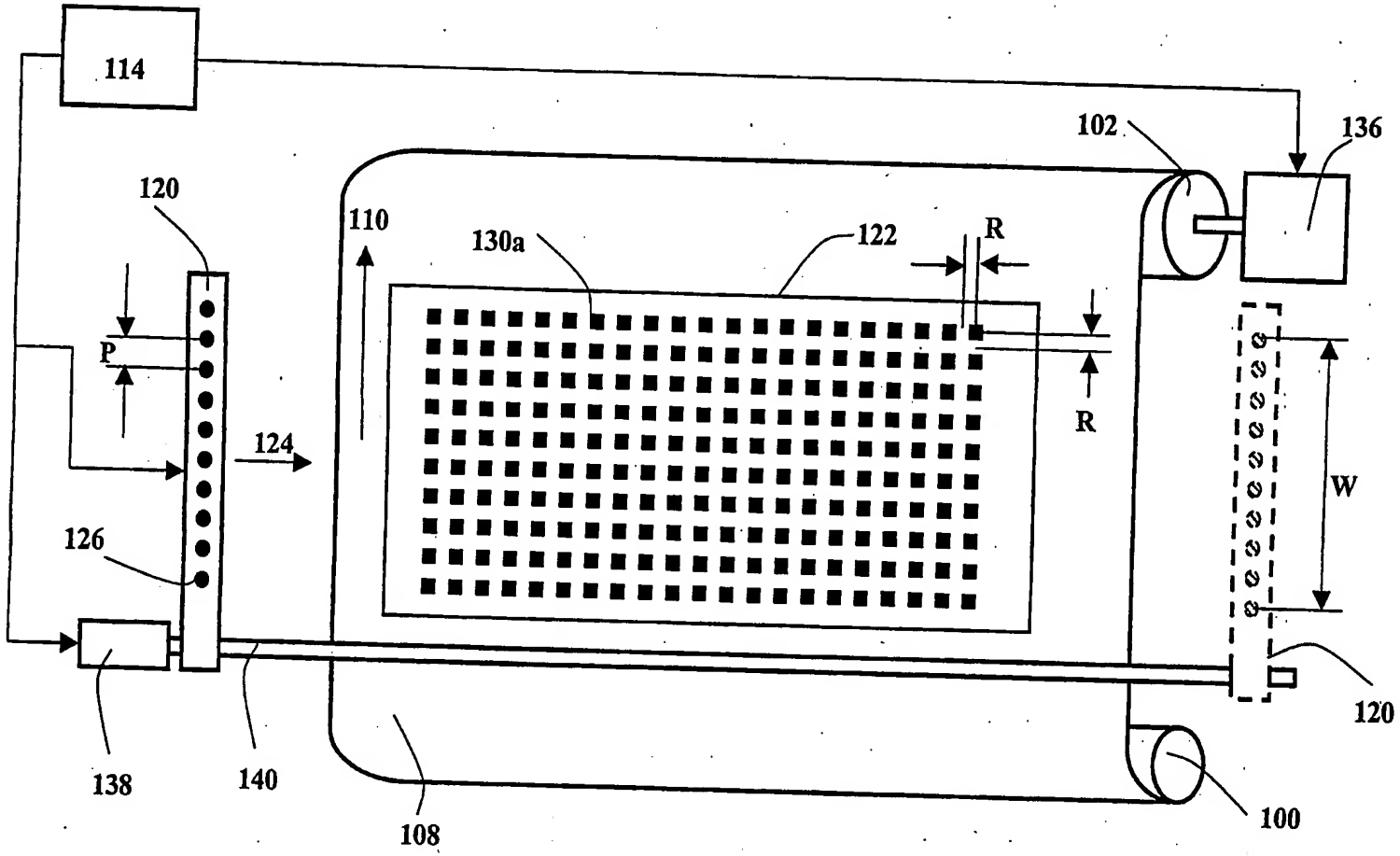


FIG. 2A. PRIOR ART

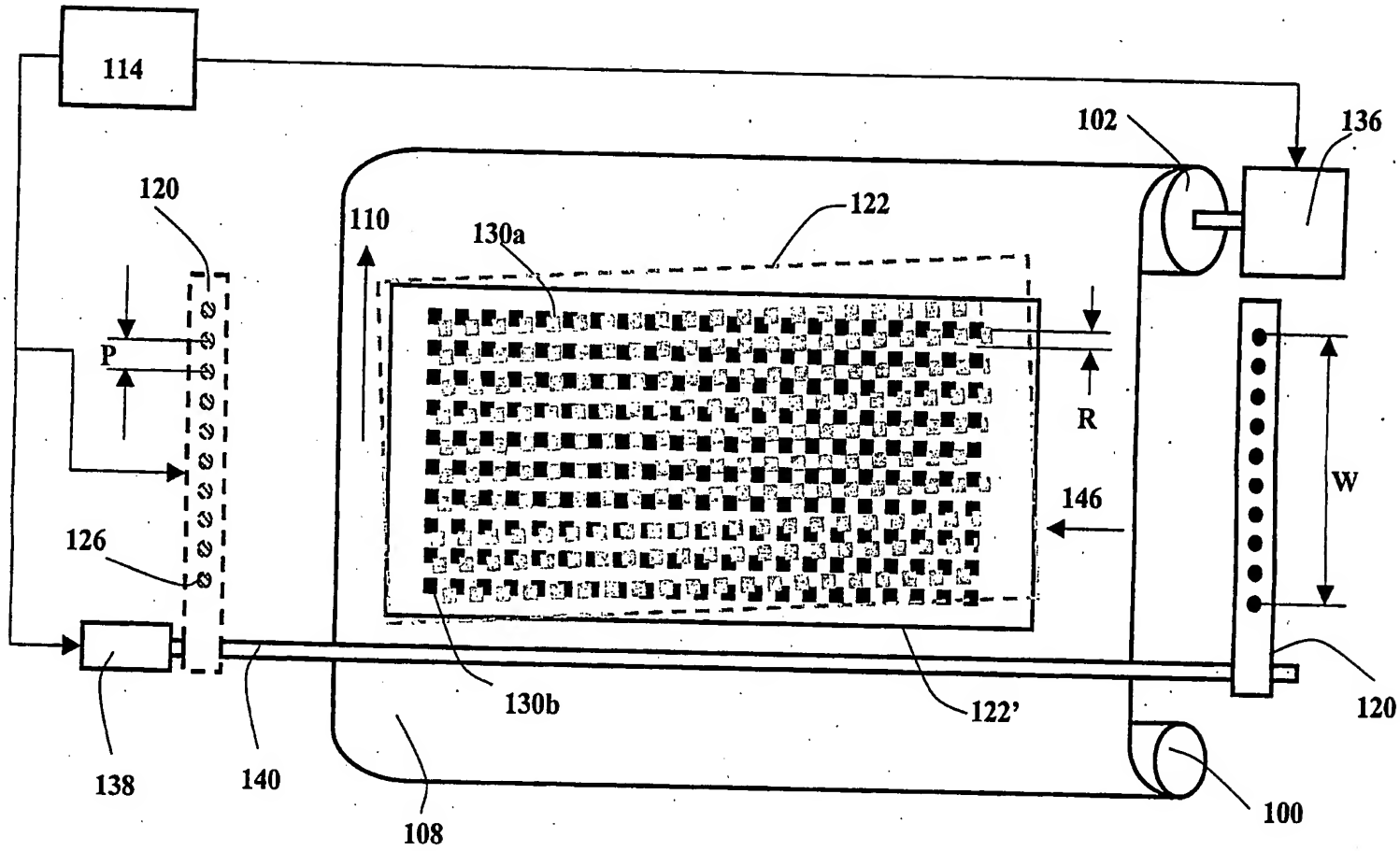


FIG. 2B. PRIOR ART

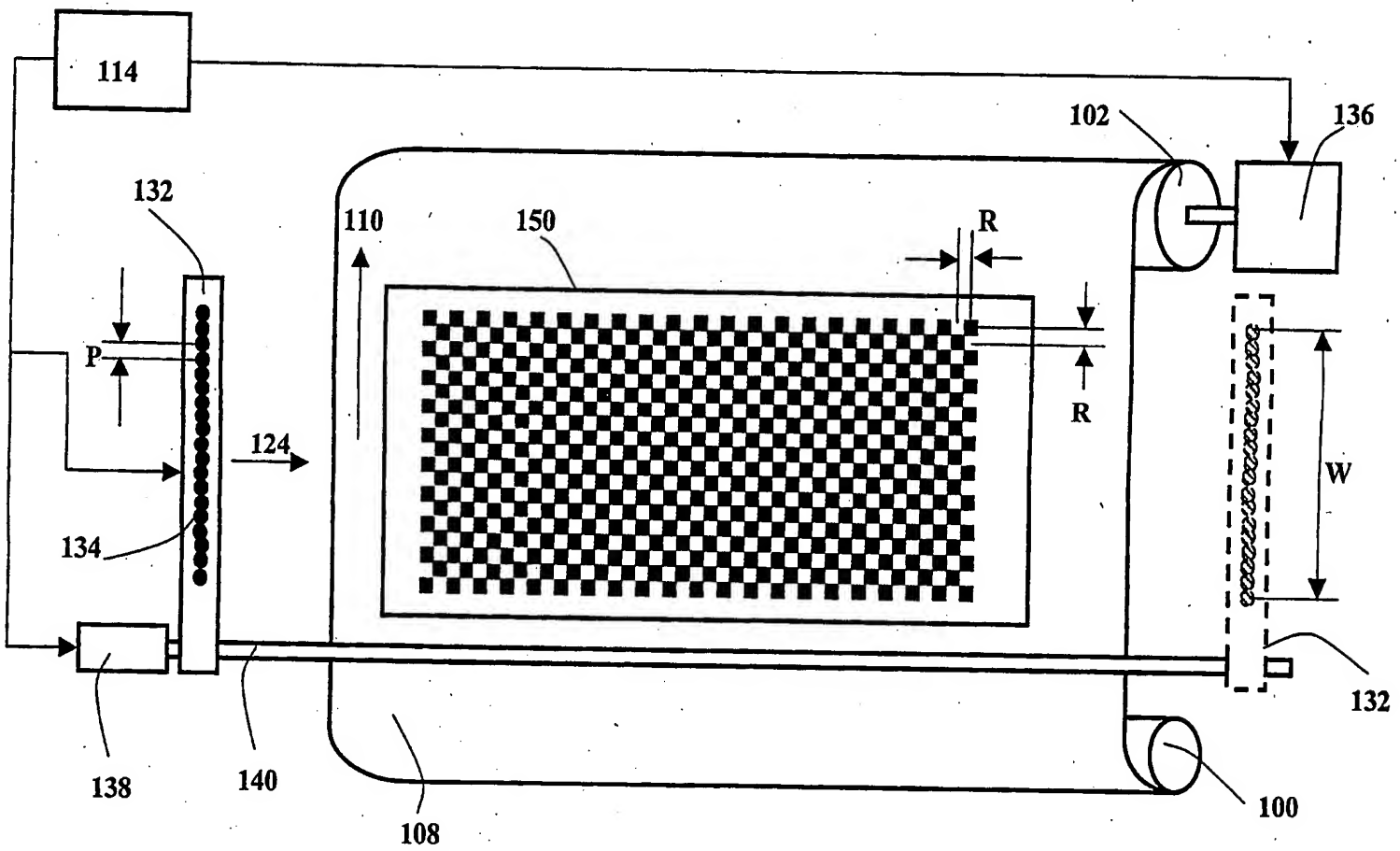


FIG. 3.

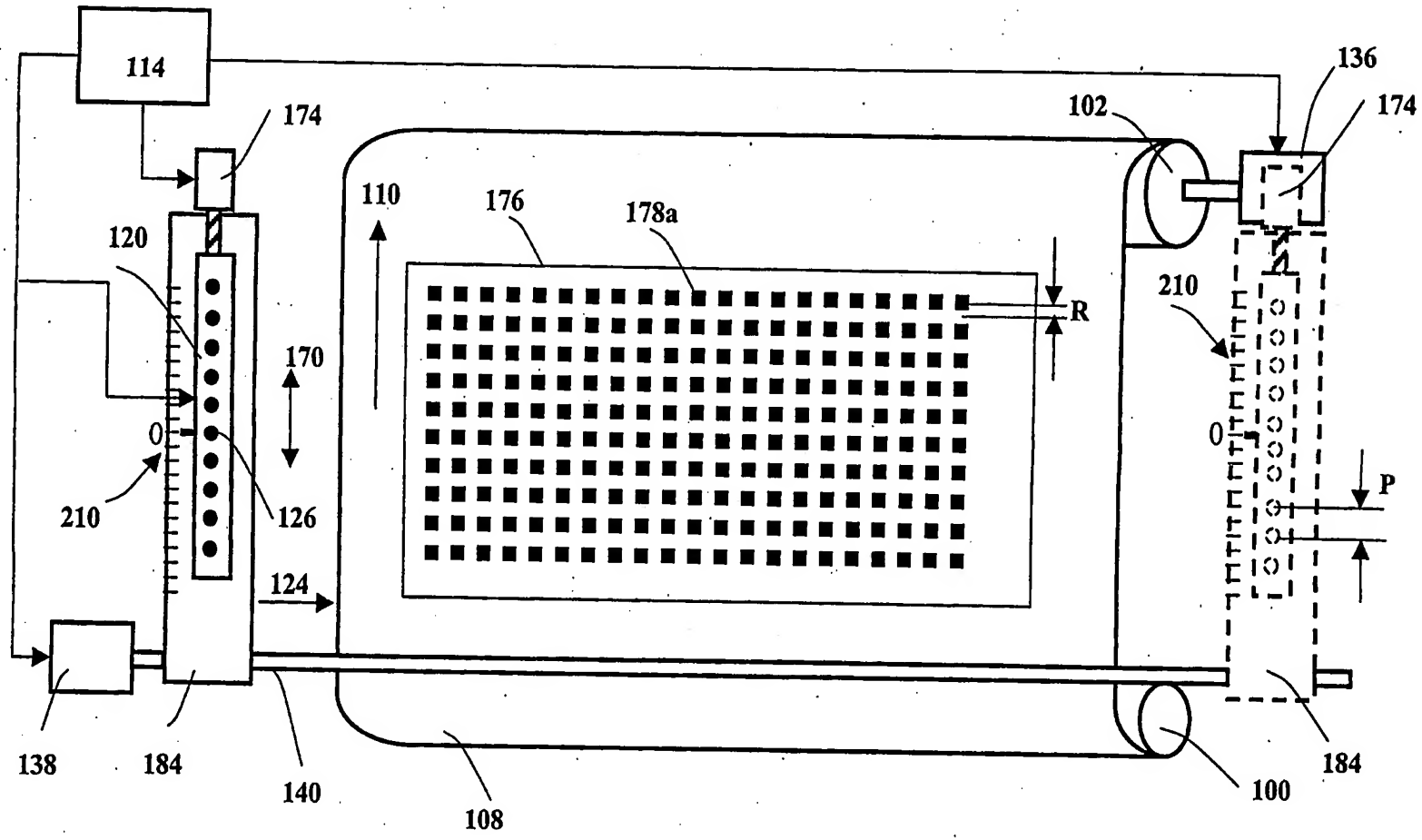

114
174
120
110
176
178a
102
136
174
210
R
170
0
210
126
124
P
0
138
184
140
108
100
184

FIG. 4A.

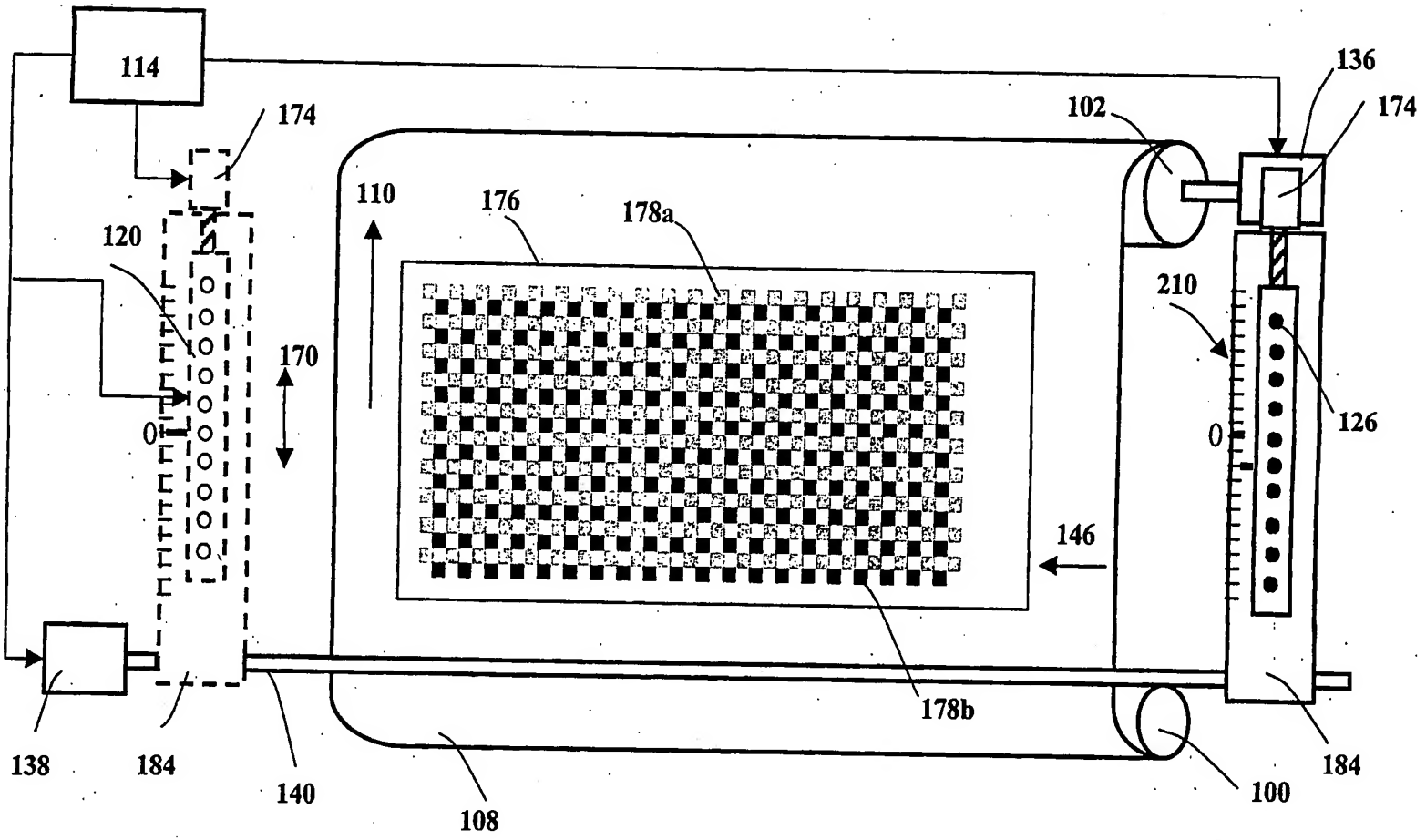

114
174
120
170
110
176
178a
102
136
174
210
126
146
178b
138
184
140
108
100
184

FIG. 4B.

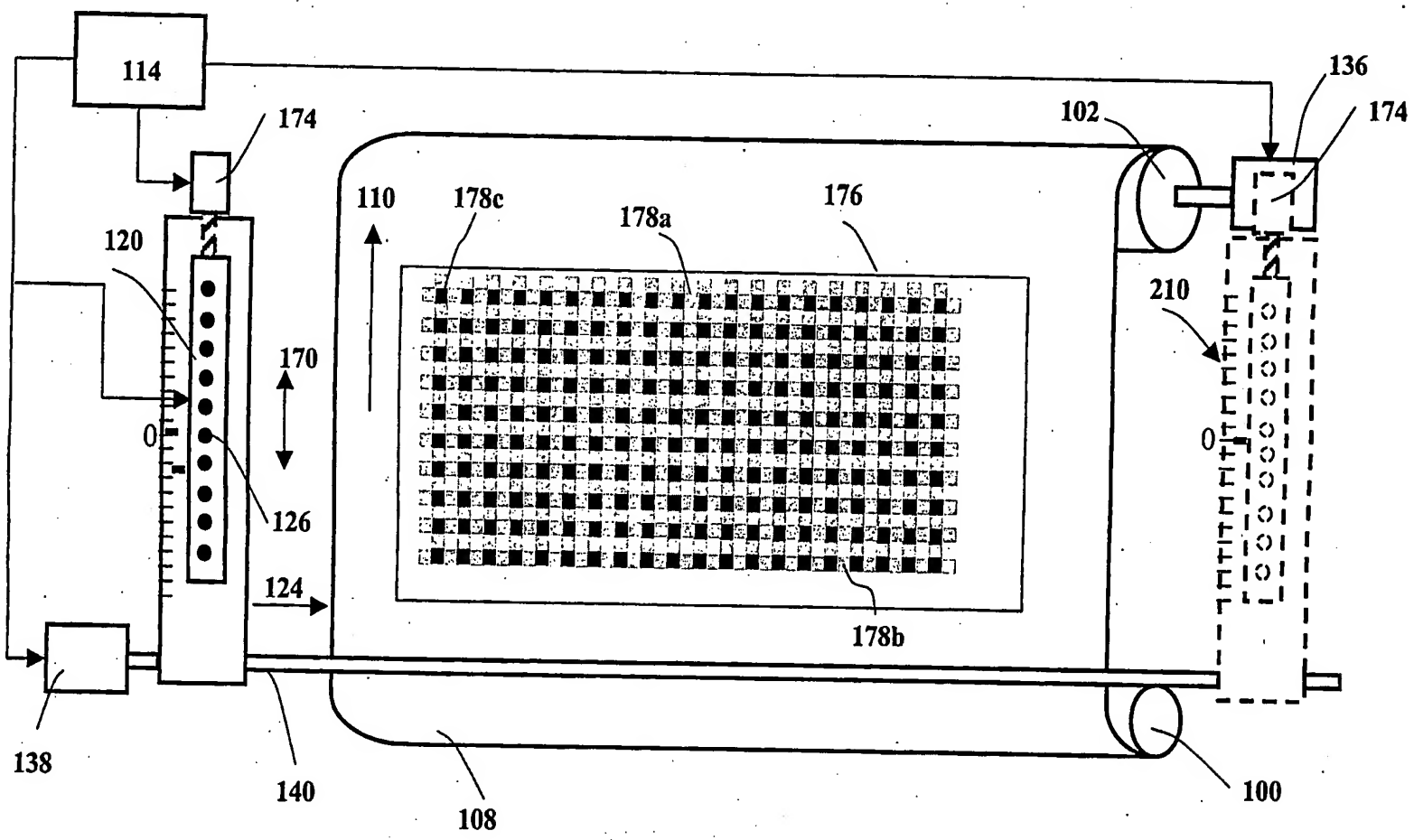
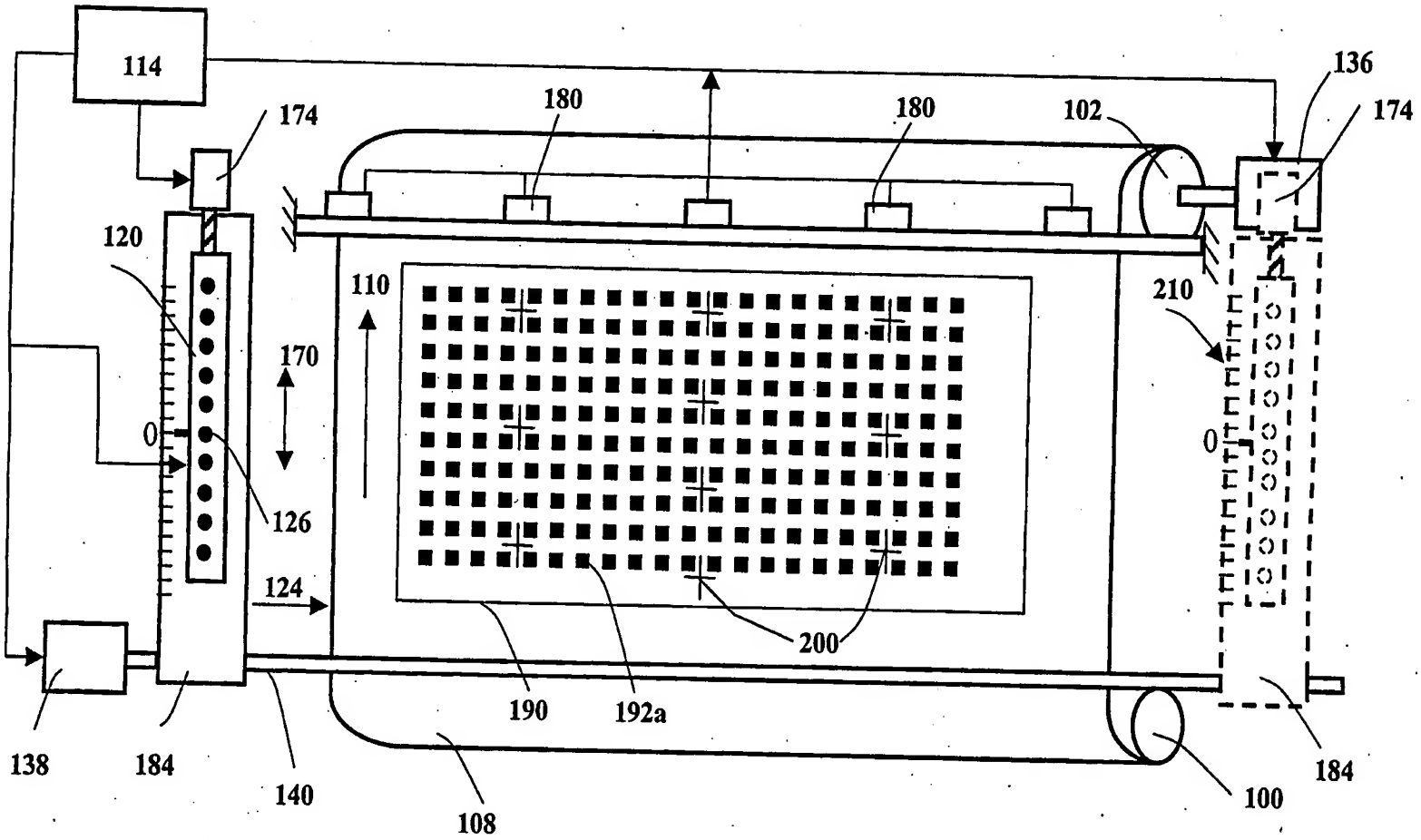

114
174
120
0
170
126
124
138
140
108
110
178c
178a
176
178b
102
136
174
210
0
100

FIG. 4C.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174
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174
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210
170
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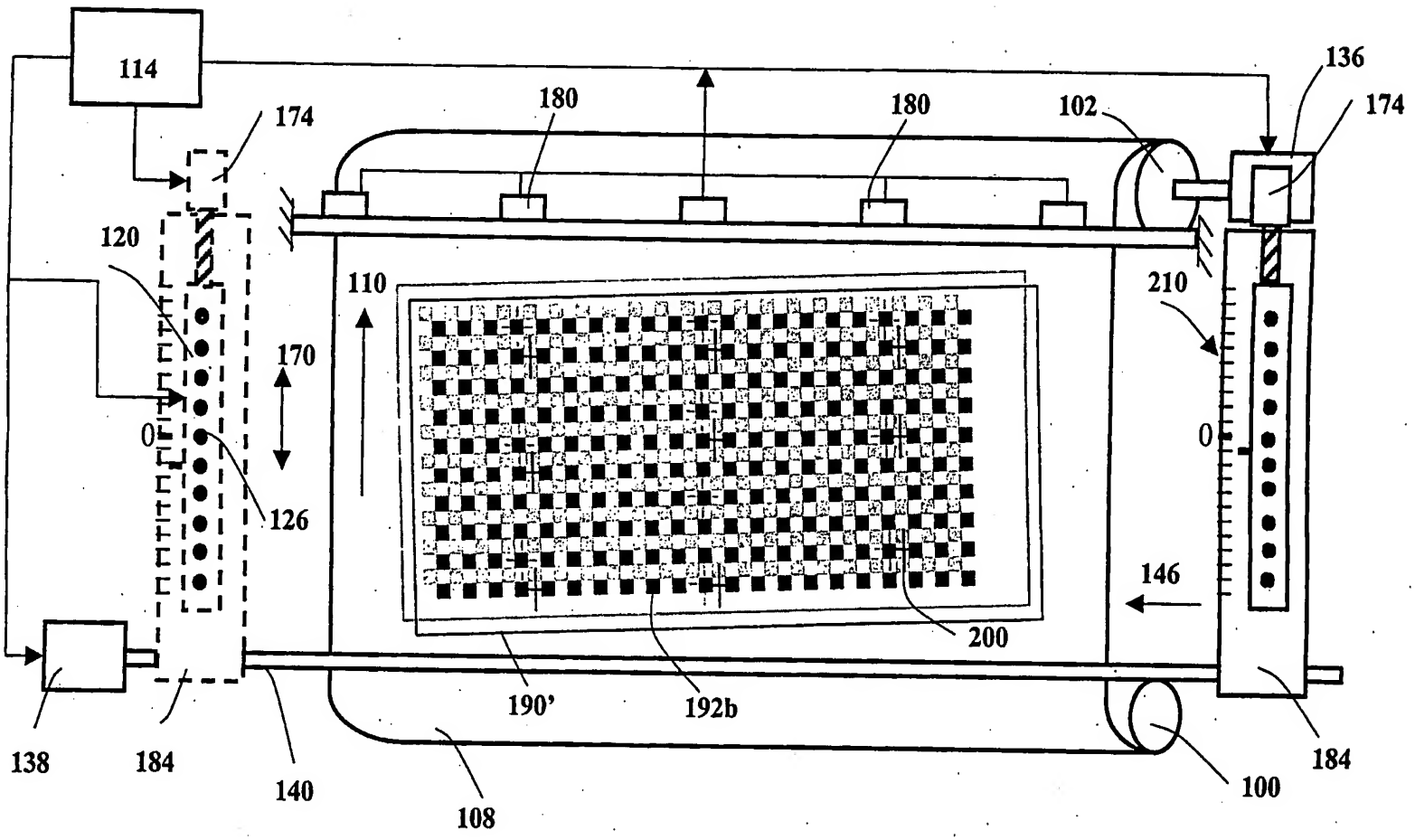
0
126
124
200
190
192a
138
184
140
108
100
184

FIG. 5A.


114
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170
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0
126
146
200
190'
192b
138
184
140
108
100
184

FIG. 5B.

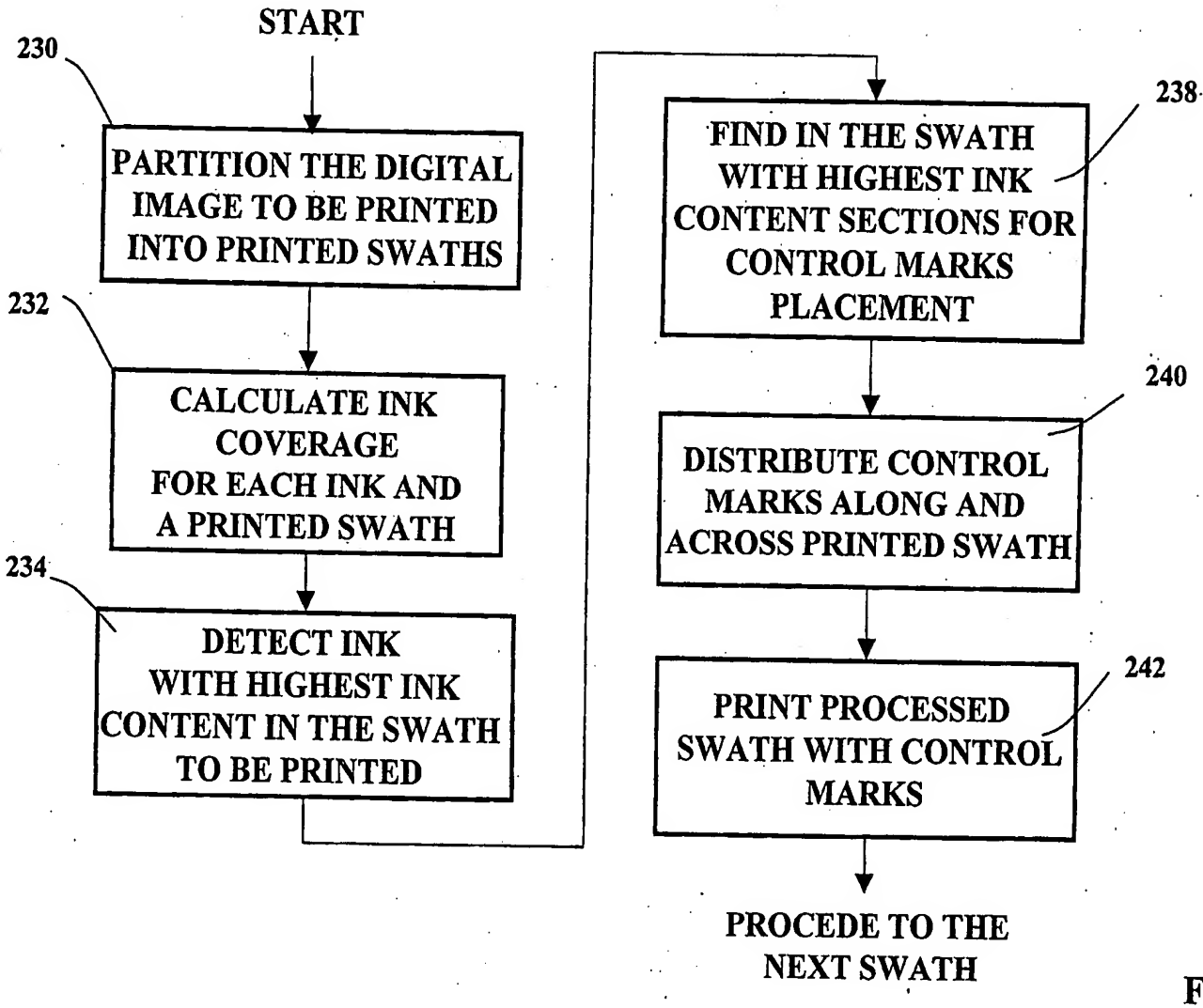
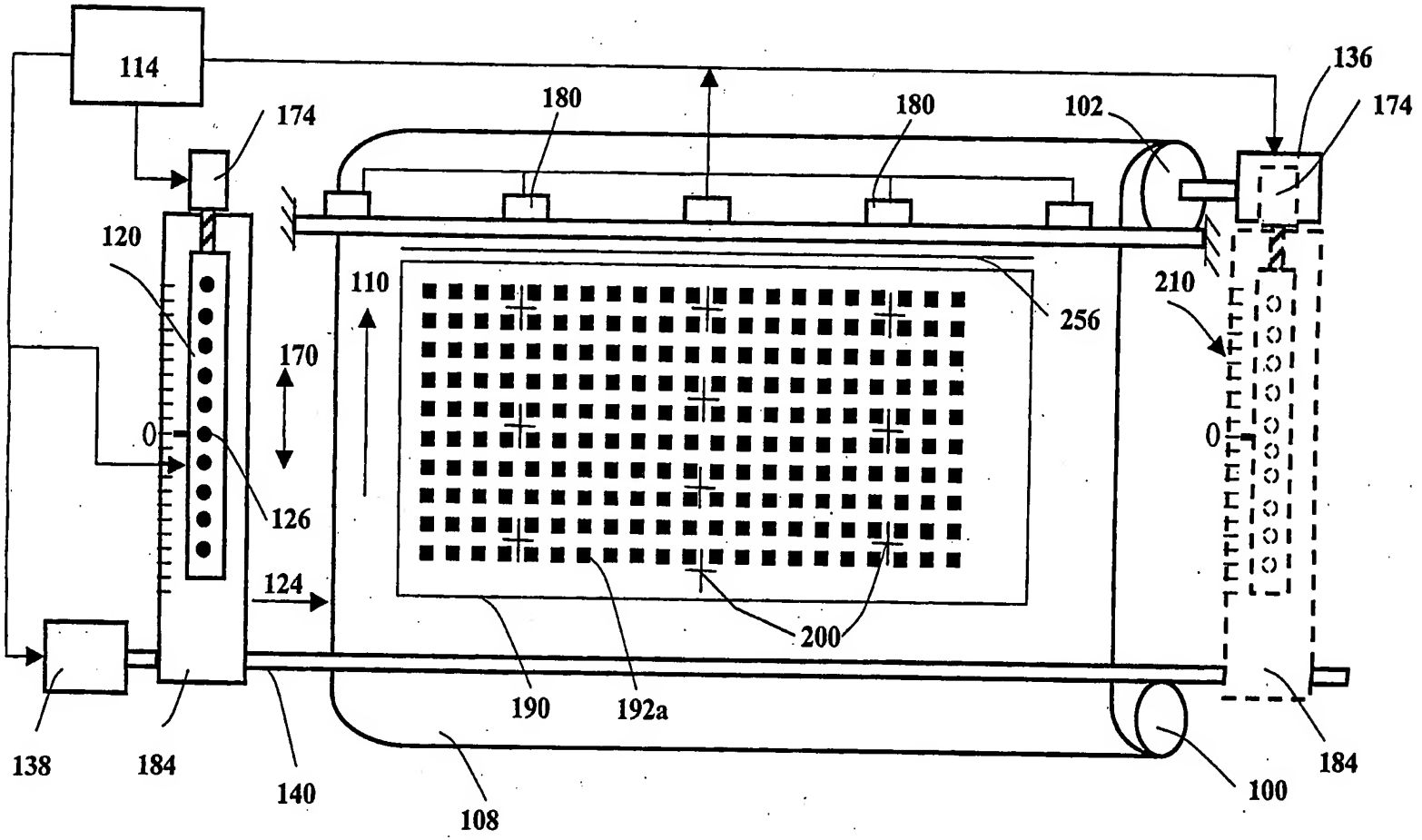

START
230
PARTITION THE DIGITAL IMAGE TO BE PRINTED INTO PRINTED SWATHS
232
CALCULATE INK COVERAGE FOR EACH INK AND A PRINTED SWATH
234
DETECT INK WITH HIGHEST INK CONTENT IN THE SWATH TO BE PRINTED
238
FIND IN THE SWATH WITH HIGHEST INK CONTENT SECTIONS FOR CONTROL MARKS PLACEMENT
240
DISTRIBUTE CONTROL MARKS ALONG AND ACROSS PRINTED SWATH
242
PRINT PROCESSED SWATH WITH CONTROL MARKS
PROCEDE TO THE NEXT SWATH

FIG. 6.


114
174
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192a
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108
100
184

FIG. 7.

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION CONCERNING
SUBMISSION OR TRANSMITTAL
OF PRIORITY DOCUMENT

(PCT Administrative Instructions, Section 411)

To:

BRONSTEIN, Rafi
c/o Scitex Vision Ltd.
5C Hatzoran Street, P. O. Box 8743
New Industrial Area
42505 Netanya
ISRAEL

Date of mailing *(day/month/year)* 23 May 2005 (23.05.2005)	
Applicant's or agent's file reference Doc 107-110	**IMPORTANT NOTIFICATION**
International application No. PCT/IL05/000326	International filing date *(day/month/year)* 23 March 2005 (23.03.2005)
International publication date *(day/month/year)*	Priority date *(day/month/year)* 01 April 2004 (01.04.2004)
Applicant SCITEX VISION LTD. et al	

1. By means of this Form, which replaces any previously issued notification concerning submission or transmittal of priority documents, the applicant is hereby notified of the date of receipt by the International Bureau of the priority document(s) relating to all earlier application(s) whose priority is claimed. Unless otherwise indicated by the letters "NR", in the right-hand column or by an asterisk appearing next to a date of receipt, the priority document concerned was submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b).

2. *(If applicable)* The **letters "NR"** appearing in the right-hand column denote **a priority document which, on the date of mailing of this Form, had not yet been received by the International Bureau** under Rule 17.1(a) or (b). Where, under Rule 17.1(a), the priority document must be submitted by the applicant to the receiving Office or the International Bureau, but the applicant fails to submit the priority document within the applicable time limit under that Rule, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

3. *(If applicable)* **An asterisk (*)** appearing next to a date of receipt, in the right-hand column, denotes **a priority document submitted or transmitted to the International Bureau but not in compliance with Rule 17.1(a) or (b)** (the priority document was received after the time limit prescribed in Rule 17.1(a) or the request to prepare and transmit the priority document was submitted to the receiving Office after the applicable time limit under Rule 17.1(b)). Even though the priority document was not furnished in compliance with Rule 17.1(a) or (b), the International Bureau will nevertheless transmit a copy of the document to the designated Offices, for their consideration. In case such a copy is not accepted by the designated Office as the priority document, Rule 17.1(c) provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

Priority date	Priority application No.	Country or regional Office or PCT receiving Office	Date of receipt of priority document
01 April 2004 (01.04.2004)	161211	IL	20 May 2005 (20.05.2005)
01 April 2004 (01.04.2004)	161210	IL	20 May 2005 (20.05.2005)

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